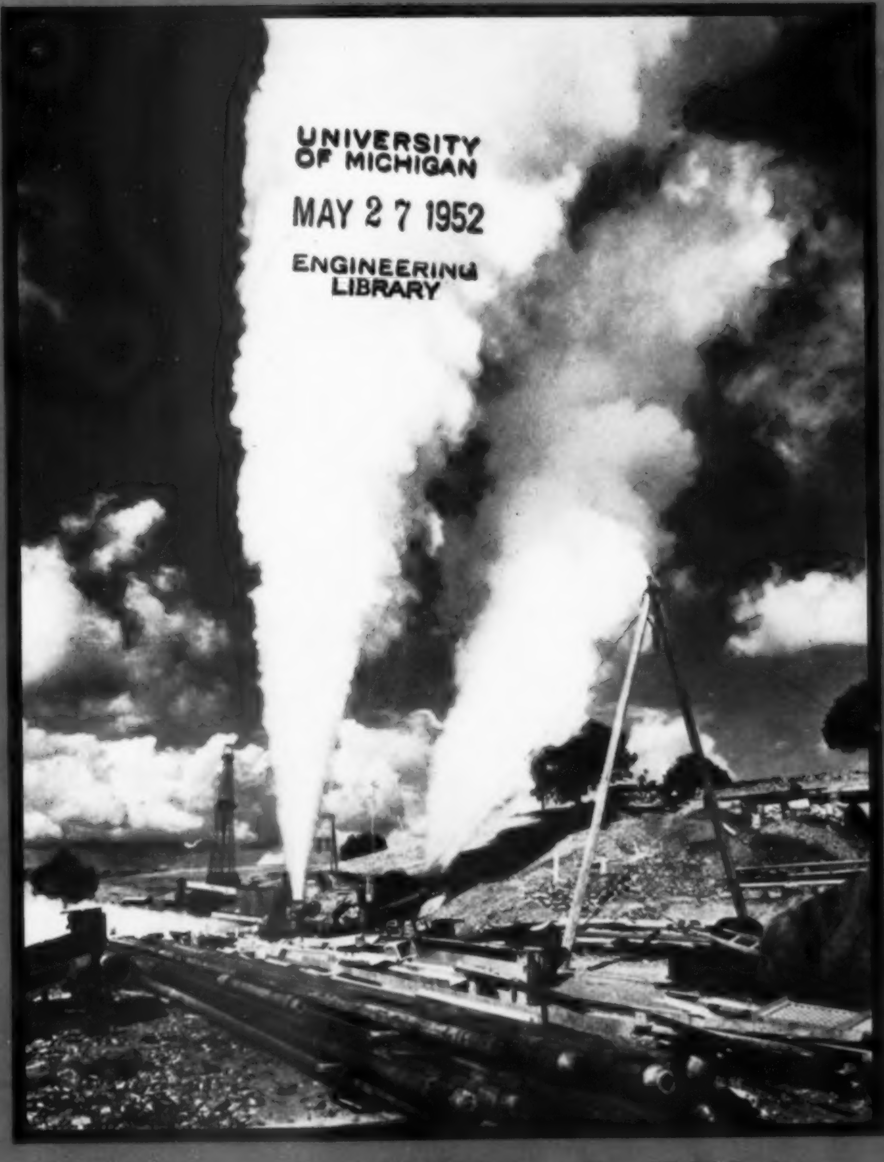
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

May 1952



This natural steam well at Larderello, Italy, produces 660,000 lb of steam per hour; see page 53 for further information.

AMER POWER STATION ›

BURNING FURFURAL RESIDUE ›

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 23 **No. 11**

May 1952

Feature Articles

Editorials

Departments

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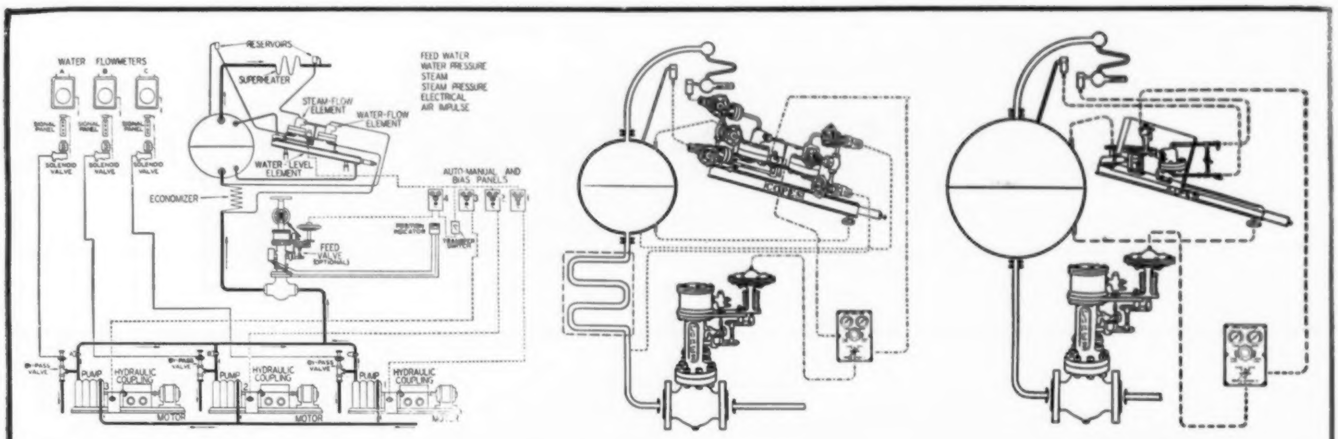
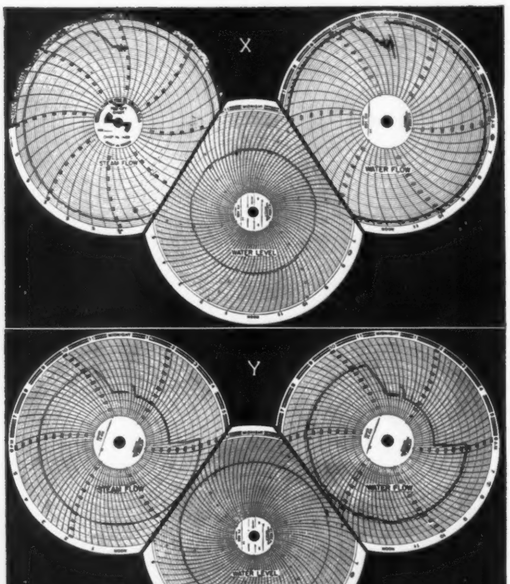


"A"—COPES Balanced Flow (3-influence) Control applied to hydraulic couplings of three pumps feeding boiler. Minimum Flow Control System also shown.

"B"—COPES Balanced Flow Regulator feeds boiler according to balanced influences of water level, steam flow and feed water flow.

"C"—COPES Flowmatic Regulator, air operated, actuated by water level and steam flow. Most modern design of the original 2-element control.



Which Control System Produced Which Charts?

"X"—Steam-flow, water-flow and water-level charts for a C-E-S Steam Generator. Peak load capacity: 750,000 pounds per hour.

"Y"—Corresponding charts for a Babcock & Wilcox Radiant Type Boiler. Peak load capacity: 425,000 pounds per hour.

"Z"—Similar charts for a C-E-S Radiant-Type Steam Generator. Maximum evaporation: 1,150,000 pounds per hour.

Each of these three COPES Boiler Feed Control Systems is used in a different utility plant. Results with each system are shown by one set of charts. You'll find little difference in gearing of feed to steam output or water level stabilization, because COPES always designs for the individual operating conditions. The number of control influences is unimportant. Try matching Charts "X", "Y" and "Z" to the correct control systems—then mail the coupon. The first 25 to do so will receive a useful gift.

NORTHERN EQUIPMENT DIVISION
CONTINENTAL FOUNDRY & MACHINE COMPANY
ERIE, PENNSYLVANIA

Here's how I'd match the charts and control systems:

Charts "X" were from the boiler with Control System ☐
Charts "Y" were from the boiler with Control System ☐
Charts "Z" were from the boiler with Control System ☐

NAME
POSITION
COMPANY
ADDRESS
CITY STATE

COPES

BOILER FEED WATER REGULATION

COMBUSTION

Editorials

A Century of Engineering

As previously mentioned in these columns 1952 will mark the one-hundredth anniversary of the founding of the American Society of Civil Engineers—the first national society of civilian engineers in the United States. Advantage is being taken of this occasion to observe a nationwide Centennial of Engineering to commemorate the tremendous advances that have been brought about by the various branches of engineering during this period. To this end various engineering societies and bodies, starting with the American Power Conference in March, scheduled their spring and summer meetings in Chicago, culminating in a Convocation to be held in that city from September third to thirteenth.

Although the so-called "industrial revolution" was in progress abroad prior to 1852, and a start had been made in this country, the last hundred years contributed more to advanced living standards, through scientific research and engineering developments, than the previous centuries combined. It has seen the birth and phenomenal growth of the central station industry with its influence on industrial expansion and domestic living; undreamed-of advances in travel and communications; developments in chemistry that have created innumerable new products and processes; and the establishment of engineering education on a plane that has placed this profession on a par with the older professions of law and medicine.

The preliminary plans for the Convocation indicate that this will be an outstanding event that should command the attendance of all engineers who can spare the necessary time.

What About the "How" in "Know-How"?

Languages are in a continual state of flux, and ofttimes words may be combined to express old ideas more aptly in new ways. A good example is the expression "know-how" which came into vogue during World War II. At present it serves as a symbol of what some persons wistfully consider widespread American superiority in technology and is associated with President Truman's Point Four Program.

Emphasis has largely been on the meaning of the word "know," while the "how," by comparison, has been neglected. One reason for this is that engineers characteristically pay little attention to the underlying modes of their daily activities, despite the use of certain mental tools which constitute the "how" of their efforts.

Basically, engineering thought and action have much in common with other endeavors. It is vitally necessary, at the outset, that the engineer *develop a sound philosophy of life*. Logically, it should encompass a belief in the scientific method, the fundamental tool of science and engineering. However, it may be as all-inclusive as the personality and the basic faith of the individual dictate, taking into consideration his educational background, environment and experience.

To *plan effectively* is an exceedingly important function of engineering. The engineer learns many of his most important lessons from the apparently trivial and insignificant happenings that others take for granted, and he generally verifies these observations by exacting experiments. Two related techniques that are fairly commonplace, though not often explicitly expressed, are the traits of "being skeptical of the obvious" and "succeeding by failing intelligently."

Planning is more effective when the engineer is gifted with or acquires the skill to *create intuitively*. He should realize that his work has artistic and esthetic aspects, for in his professional practice he is neither an unimaginative creature nor a mere mechanical automaton. Instead of following outmoded traditions, he can assert the type of leadership capable of creating technical marvels, using an opportune combination of intuition and logical analysis. His creative efforts are most effective, it might be added, when the results are simplicity, utility and beauty.

Another phase of the "how" in engineering was emphasized by Philip Sporn in his challenging address, "Vision in Power," presented before the recent American Power Conference. As he implied, the successful engineer should develop the quality to *envision foresightedly*. If a particular undertaking has failed, he should be capable of seeing beyond the immediate obstacles to the more distant possibilities, since it is a truism that technical problems seldom have but one method of approach and but one solution. Along with his analytical ability, the outstandingly competent engineer must become endued with some of the spirit of civilization's great spiritual and intellectual pioneers. Only in this way can engineering continue to "by pass the conventional and the possible" in order to "achieve the unconventional and the impossible."

To glibly use the expression "know-how" is not enough. But knowing how know-how comes into being has genuine significance in the understanding of modern technological achievements. And engineers themselves, it might be concluded, can profit by a keener awareness of the "how" of their day-by-day pursuits.

AMER POWER STATION at Geertruidenberg, The Netherlands

By IR. F. A. W. H. VAN MELICK

Chief Engineer, N. V. Provinciale Noordbrabantsche Electriciteits-Mij.

Description of a new public utility plant of 121,000 kw burning pulverized anthracite and employing a storage system. There are two main turbine-generators, an auxiliary turbine-generator and four steam generating units with steam conditions of 1140 psig and 950 F. This is the first section of a station of 300,000 kw ultimate capacity.

THE N. V. Provinciale Noordbrabantsche Electriciteits-Mij serves an area of 1970 sq mi, embracing a population of approximately 1¼ million. Of its total electric generation, 46.5 per cent currently goes to industrial establishments, 36 per cent to various municipalities, 5.2 per cent to other grid members and 12.3 per cent represents transmission losses and auxiliary power.

Fig. 1—General view of station

Postwar growth in electrical demand rendered the existing 150,000-kw Donge Power Station inadequate, and condensing water limitations there made extension of that plant inadvisable. Therefore, site for a new station was selected just beyond where the Donge River empties into the larger Amer and not far from the city of Geertruidenberg; see Fig. 2. Here there was not only ample condensing water for an ultimate capacity of 300,000 kw, but deep water made possible coal delivery by coastal vessels. The ground level at the site was raised about 20 ft with dredged earth to place it well above the highest tide level, and decision was reached to make the initial installation 121,000 kw.

The first unit was placed in service last December and the second this spring. By next year 150,000-volts and 100,000-volts transmission grids will have been completed for connecting all the important power stations in The Netherlands.

Each of the 50,000/56,000-kw main turbine-generators is supplied with steam at 1140 psig, 950 F at the throttle by two 290,000-lb per hr three-drum C-E steam generating units vertically fired with pulverized anthracite[1] which is prepared by Raymond bowl mills. Auxiliary power, capable of serving the ultimate installation, is provided by installation of an auxiliary turbine-generator of 7200/9000 kw and by two 10-kv connections from the Donge plant. All essential auxiliaries are motor-driven and in duplicate with the drives divided between these two power sources as a measure of safety.

Selection of the number and size of units was influenced by the annual load growth of approximately 15,000 kw and by the fact that the night demand ranges from one-quarter to one-third of the day demand. The capacity factor of the system has never exceeded 0.4 to 0.5. On this basis, the two 50,000/56,000-kw turbine-generators and four 250,000–290,000-lb-per-hr boilers were chosen in the belief that this combination would provide the desired operating flexibility while also enabling stable

[1] The analysis corresponds more to what we are accustomed in the United States to designate as semi-anthracite.—EDITOR.

Fig. 2—Location of plant with reference to Amer River and town of Geertruidenberg

Fig. 3—Where Donge flows into the Amer

ignition of the anthracite to be maintained during the night load.

Heat balance studies indicated a net station heat rate at the most economical load of 11,100 Btu per kwhr and a probable yearly average not exceeding 11,900 Btu.

A plan showing the station layout is given in Fig. 7 and an elevation in Fig. 8. The operating floor of the turbines and boilers are at the same level and that of the feed pumps, condensers, circulating pumps, heaters, mills, forced-draft fans, compressors, etc., is at the lower level. The turbines are supported on steel frames instead of concrete to save space and facilitate the piping layout. A 140-ton crane was selected for the turbine room in order to be able to handle the step-up transformer as well as a 100,000-kw generator that is contemplated for installation later.

Main Units

The main turbine-generators, of Brown Boveri design, are of the three-cylinder, tandem-compound type with double-flow low-pressure element and a speed of 3000 rpm. There are five extraction points for 400-F feedwater heating and each unit exhausts to a 450,000-sq ft twin-flow surface condenser having a divided water box, welded shell and aluminum-brass tubes rolled at both ends. Water-jet ejectors are provided for extraction of non-condensable gases and steam ejectors for

Fig. 4—View from the harbor showing dock line and coal handling structure

quick starting. The main turbines are designed for a heat rate of 9160/9200 Btu per kwhr at 50,000/56,000 kw.

As previously mentioned, the four steam generating units are of the three-drum type, of Combustion Engineering-Superheater design, with fin-tube economizer, regenerative air preheater and bubble-type steam washer. The furnace roof, front and sides have fin tubes, the rear wall plain tubes and the bottom is of the basket type. Twelve Lopulco vertical burners fire downward through a front arch to produce a long U-shaped flame which is essential for a low-volatile, slow burning coal such as the local anthracite. Secondary air is introduced through the front wall. Bypass dampers are employed for steam temperature control.

Because of the difficult fuel situation in The Netherlands it is necessary to make provision for getting coal from various sources; hence separate storage piles and multiple bunkers to permit subsequent mixing become an important consideration. The coal for which the plant was primarily designed to burn is a Dutch anthra-

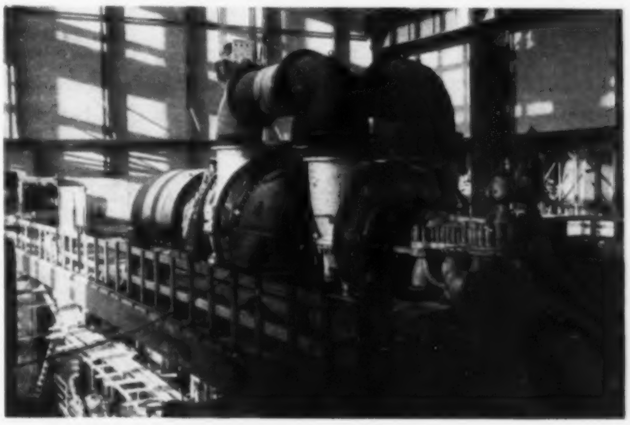


Fig. 5—Turbine-generator nearing completion

cite analyzing 64 per cent fixed carbon, 10 per cent volatile, 13 per cent moisture, 13 per cent ash and a heating value of 12,960 Btu per lb, as fired. The grindability is 60 Hardgrove.

The storage system was chosen in order to assist stable ignition of the low-volatile coal at light loads. This also permits shutting down the mills for several hours each day at substantial power saving. With a total capacity of 86 tons the pulverized coal bin is divided into two compartments, the larger for the normal fuel and the smaller, of one-sixth the capacity, for high-volatile coal. This provision permits the operator to change over the feeders supplying four burners to the higher volatile coal should this become desirable for flame stabilization; or, if desired, to mix the coals.

Between the Ljungstrom air preheater and the two induced-draft fans serving each unit is placed a wet dust collector of the Modave type which has a guaranteed efficiency of 92 per cent with a draft loss of $^{25}/_{32}$ in. at full load. In this collector the dust-laden gases pass over nine rows of enameled iron bars of special shape which are wet by a water film to entrain the fly ash. Gas temperature ahead of the air preheater is 330 F, which is

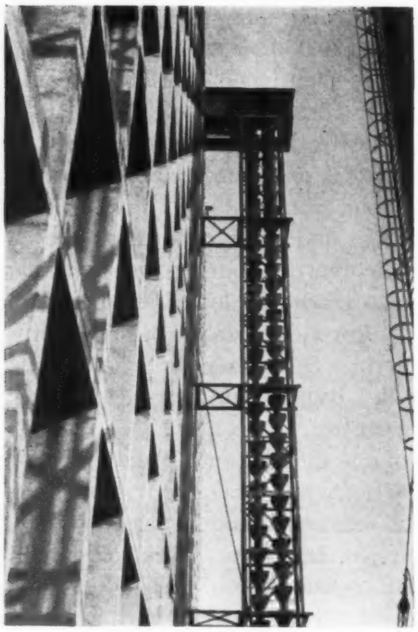


Fig. 6—Coal elevator

reduced to 185 F behind the dust collector. The induced-draft fans are protected by special paint and the ducts between the fans and stacks are treated with a bitumen product.

Ashes are removed from the furnace periodically by hydraulic means.

Each boiler has two induced- and two forced-draft fans driven by variable-speed commutator motors of 150 hp having a speed range of 320 to 960 rpm.

Two of the boilers are equipped with combustion control of the hydraulic type (oil) and the other two employ an air-controlled system.

An automatic sequential air soot blowing system was adopted after investigation had indicated it to be more economical than steam under the conditions at Amer. The effective blowing pressure at the nozzles is 250 psi.

Coal Handling

Normally, the coal is delivered to the plant by water, the ships being unloaded in the basin by a crane which empties to a hopper. A feeder at the bottom of the hopper elevates the coal to horizontal steel belts that, in turn, unload by means of traveling bridges and cross belts to storage piles in the yard. A scraper in an underground tunnel under the storage piles loads a rubber belt feeding a vertical conveyor that elevates and deposits the coal to horizontal belts running over the bunkers. Each boiler has three bunkers. The total bunker capacity for each boiler is 800 tons. Between bunker and pulverizer is a scale for each boiler, the chutes from scale to mill being of stainless steel. Relays mounted in the chutes control the coal flow.

There are six boiler feed pumps, including two spares which come into service automatically if the feedwater pressure falls below a predetermined value. The capacity of each is 220 tons per hour and ordinarily operation of one pump is sufficient to maintain normal load on one main turbine and the auxiliary turbine; but for top load with two boilers supplying a single turbine two pumps are required. The relative location of the feed pumps is shown on the accompanying flow diagram. All these pumps are motor-driven, four by slip-ring motors with speed control.

The cooling water intake is on the Amer some 270 yd downstream from the plant. Four two-stage, vertical, propeller-type, two-speed, squirrel-cage, motor-driven circulating pumps serve the two main condensers and one single-stage, two-speed vertical pump supplies the con-

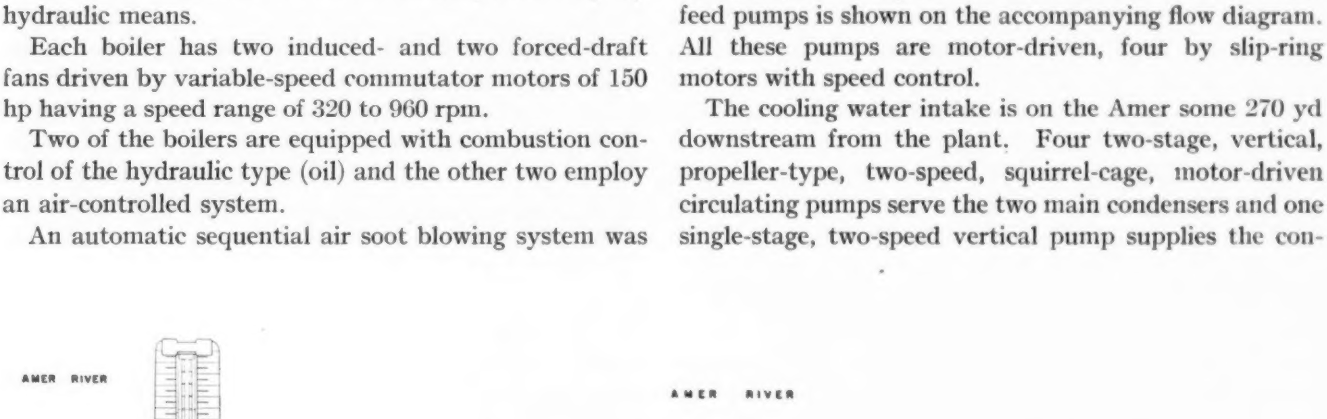


Fig. 7—Plan of station and coal storage

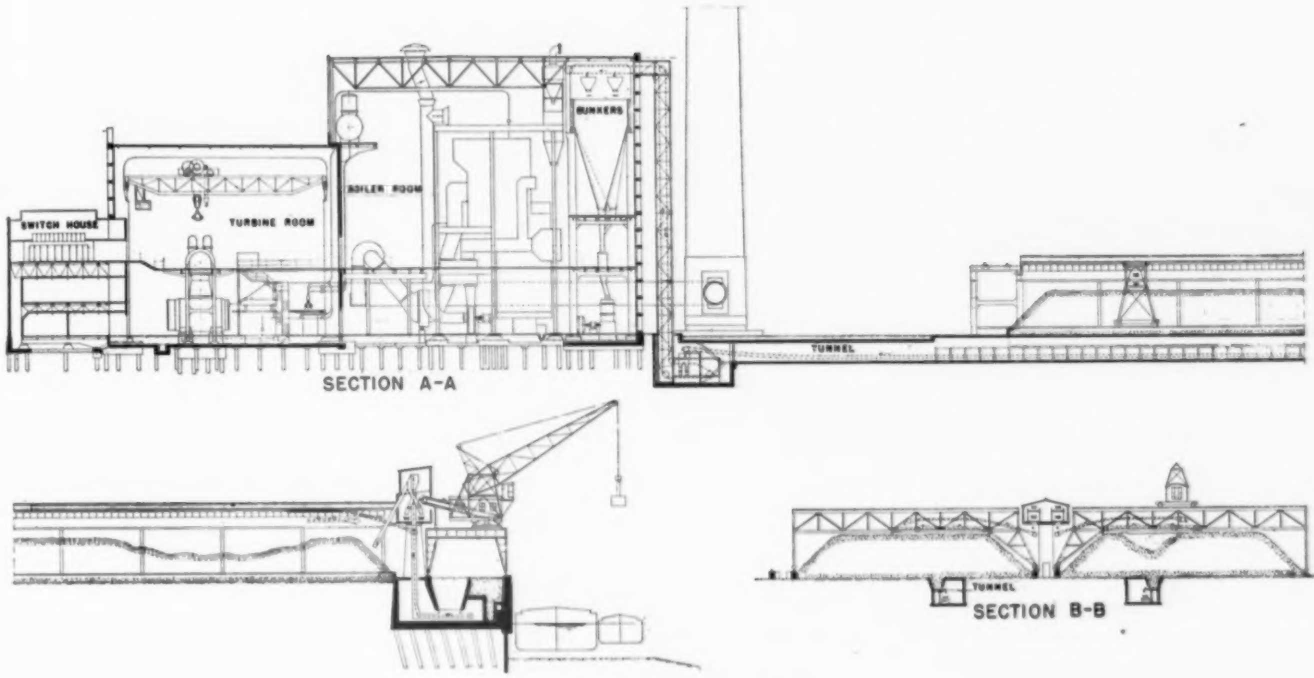


Fig. 8—Elevation of station

denser of the auxiliary turbine unit. With a normal difference of water level of about five feet, between high and low tide, sufficient submergence of the pump propellers has been provided to avoid cavitation and make foot valves unnecessary. From May to September when the water temperature is high, the pumps will run at their higher speed (585 rpm) but at other times, with a water temperature below 59 F they will run at the lower speed (488 rpm), thus effecting an estimated annual saving of 350,000 kwhr.

Screens are of the revolving type and there are two intake tunnels, in order to facilitate cleaning. The pumps are located in the screen house, which has been built sufficiently large to take care of twice the capacity, but they can be controlled from the turbine control board. All cooling water will be chlorinated.

High-Pressure Piping

The feed lines are of carbon steel of 7.5 and 5.76 in. O.D., the larger size applying to the headers and the smaller to the supply of one boiler. The steam piping, which is mostly 8.5 in. O.D., is chrome-molybdenum. All the high-pressure valves are forged and welded and of the same composition as the piping, which simplified the welding procedure. They are of the sealed-bonnet type with stellite-faced joints, the steam valves having nitrided spindles and the feedwater valves stainless steel spindles. All these valves are of the Ferranti type, with the seat diameter smaller than that at the pipe connection.

Water Treatment

Investigation revealed that it would be more expensive to purify the river water for makeup than to sink deep-wells on the power plant site; hence the latter plan was followed. This well water is high in carbonates but runs low in sulfates and chlorides. From the wells the water is de-ironed and pumped into tanks suspended from the steelwork of the bunker house. These tanks also supply the plant with service water.

The water treatment for makeup is effected by a hydrogen-zeolite process in two softeners and the effluent is freed of carbon dioxide in a special degasification tower. The remaining acid is neutralized with caustic soda using pH control equipment. The softened water is then stored in a concrete basin painted with a special rubber paint that is resistant to both acid and alkali. From this tank it is pumped to a deaerating heater.

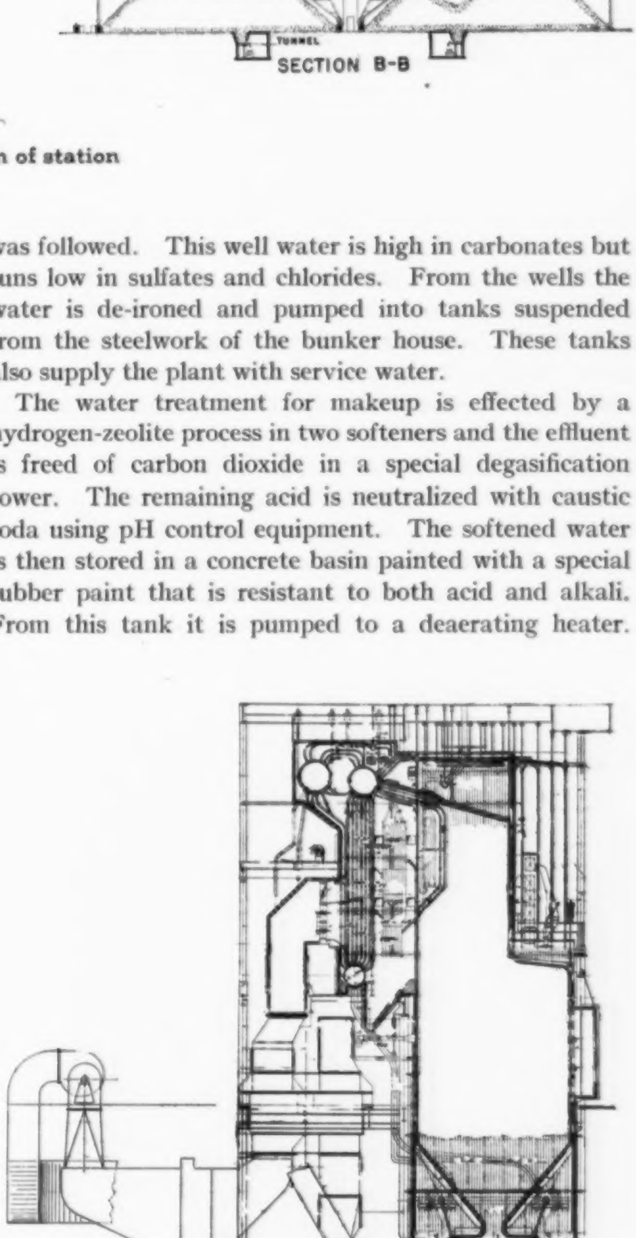


Fig. 9—Cross-section through boiler

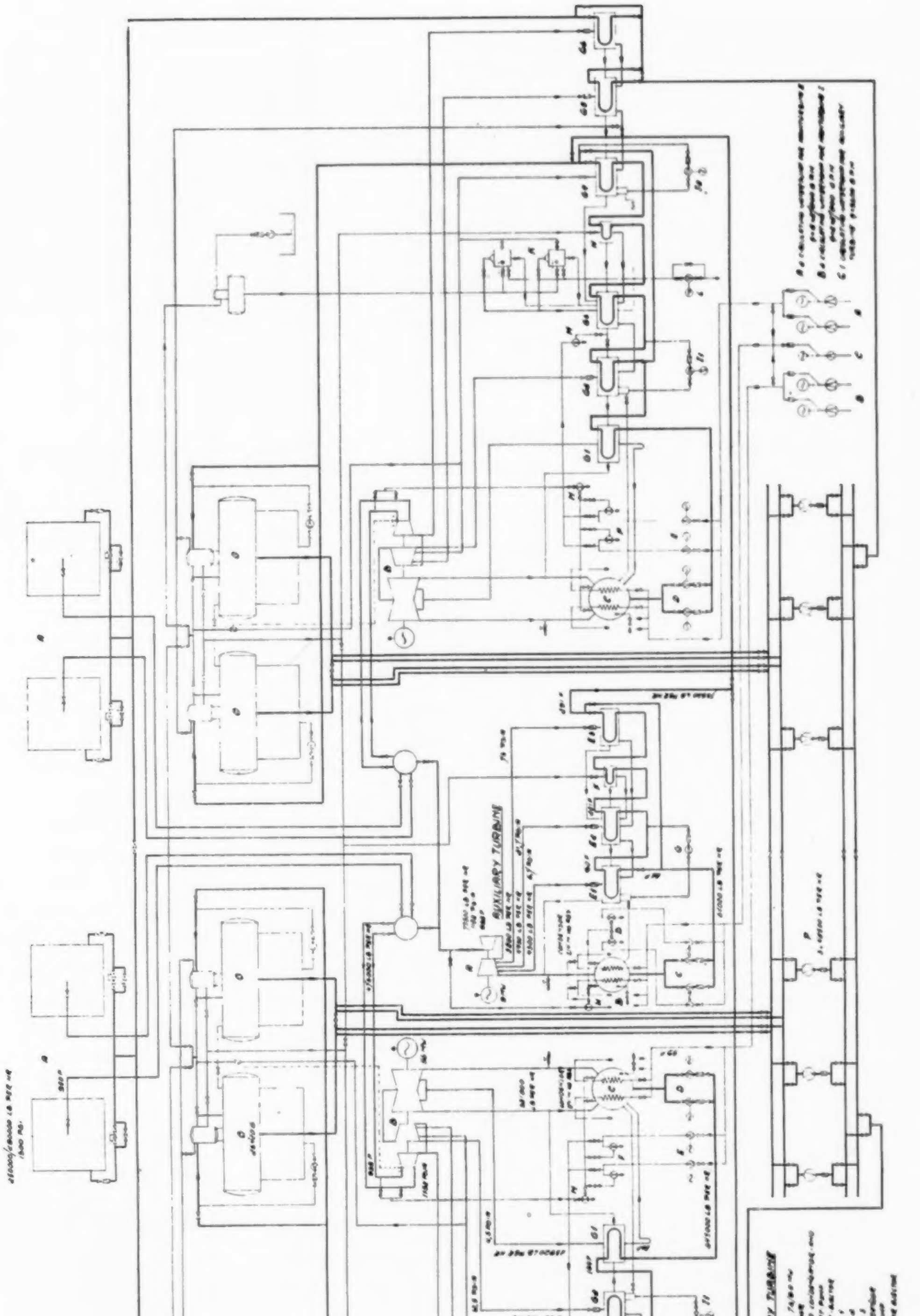
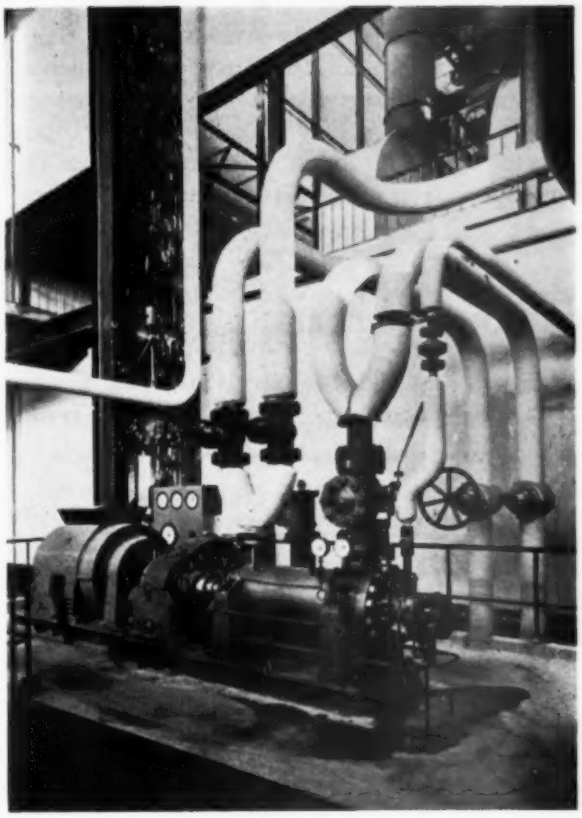
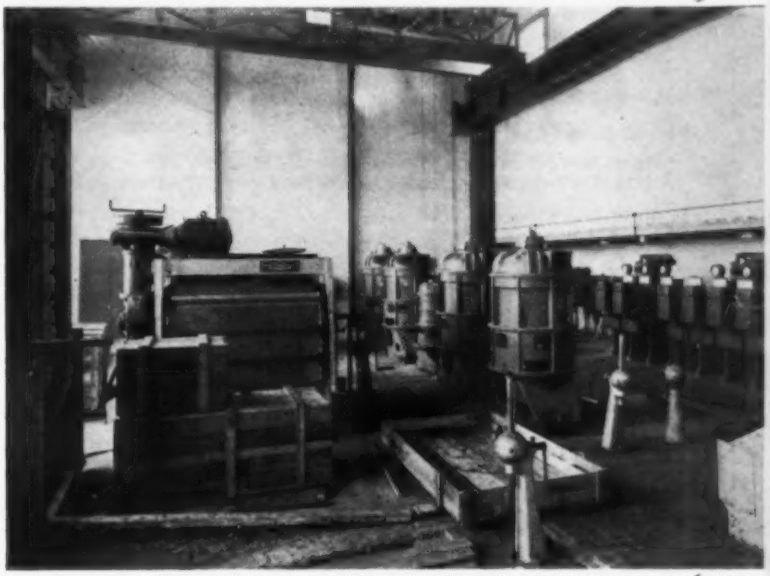


Fig. 10—Flow diagram

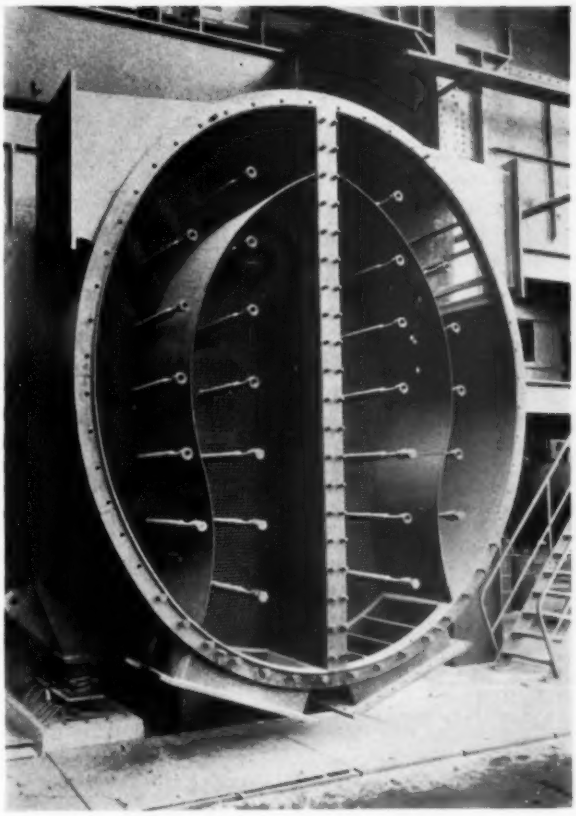


Variable-speed boiler feed pumps

Coal handling facilities showing conveyor bridge in background



View in screen house showing circulating pumps



Twin-pass divided-water-box condenser

C-E Raymond bowl mills

Although the anticipated makeup will be about one per cent, the evaporators have been designed for five per cent at full load.

Electrical Features

The main units delivered electric energy at 10,000 volts to step-up transformers which supply the transmission lines at 150,000 volts. Three 6-in. copper tubes serve as connections between generator and transformer. All essential motor-driven equipment, such as draft fans, condensate pumps, etc., is in duplicate with independent sources of supply—one the auxiliary turbine-generator and the other the connection from the Donge Station. All switchgear is of the metal-clad type.

PRINCIPAL EQUIPMENT OF AMER POWER STATION

Steam Generating Units
Three 290,000-lb per hr, three-drum type, 1300 psig, 950 F at S.O.; two-stage *Elesco* pendant superheater with bypass dampers; fin-tube economizer and Ljungstrom air preheater—*Combustion Engineering-Superheater, Inc.*
Superheat Control—*Leeds & Northrup*
Combustion Control—*Askania* (2 units) and *Hagan* (2 units)

Fuel Burning Equipment
Storage system; "Raymond" bowl mills, 20,000 lb per hr (two per boiler); Type R feeders; "Lopulco" vertical burners (12 per boiler). Designed for burning semi-Anthracite.—*Combustion Engineering-Superheater, Inc.*

Forced-Draft Fans
Eight (two per boiler); 53,000 cfm at 12 in. water driven by 150 hp variable-speed motors (320–960 rpm).—*N. V. Werkspoor*

Induced-Draft Fans
Eight (two per boiler); 73,500 cfm at 9.05 in. water driven by 150-hp motors with variable-speed control.—*N. V. Werkspoor*
Fan Motors.—*EMF Dordt*

Primary Air Fans and Mill Vent Fans
Eight each (9700 and 13,500 cmf, respectively).—*Mach. fabr. Kennemer*

Boiler Feedwater Control
Copes "Flowmatic."—*Northern Equipment*

Soot Blowers
Automatic sequential air type.—*Vulcan Soot Blower*

Dust Collectors
"Modave" wet type.—*Mach. fabr. Kennemer*

Coal Bunkers
Four, 43,450 cu ft each.—*De Vries Robbé*

Coal Scales
20 tons per hr.—*N. V. Servobalans*

Coal Handling—*Conrad-Stork*

Water Supply
Deepwells, two, 525 ft depth; 300–440 gpm.—*Visser & Smit*
Deepwell pumps
Two, 316 gpm, 2900 rpm.—*Wülfel*

De-Ironing System
Capacity 660 gpm.—*Reineveld*

Water Storage Tanks
Seven of 35 tons each.—*De Vries Robbé*

Water Softeners
Capacity 200 gpm.—*Reineveld*

Main Turbine-Generators
Two 50,000–56,000 kw, 3000 rpm, 1140 psig, 932 F, 1.14 in. Hg, 5 bleed points, 400 F feedwater temperature, air-cooled generators and pilot exciters.—*Brown Boveri*

Main Condensers
Two 49,500 sq ft twin-pass divided water box.—Designed by *B.B.C.;* built by *Rotterd, Droogdok Mij.*

Condensate Pumps
Four, 4-stage.—*Sulzer* (*Sw*)
Driven by 100-hp squirrel-cage motors.—*B.B.C.*

Circulating Water Pumps
Four 2-stage vertical propeller type, 22,200–27,800 gpm.—*Vickers-Armstrong*
Driven by two-speed squirrel-cage motors.—*B.B.C.*

Ejectors
Each turbine has 2 water-jet air ejectors and one steam ejector.—*B.B.C.*

Water Pumps
Four for air ejectors.—*B.B.C.*

Auxiliary Turbine-Generator
One 7200–9000 kw, 3000-rpm, 1140 psig, 932 F, 1.14-in. Hg exhaust; 3 bleed points.—*Brown Boveri*

Auxiliary Condenser
One 7950 sq ft, three-pass, divided water box.—*B.B.C.*

Circulating Pump for Auxiliary Condenser
One, single-stage, 9300–7000 gpm, 31–21 ft driven by B.B.C. squirrel-cage two-speed motor.—*Jaffa*

Revolving Screens
Three of 44,000 gpm.—*Blakeborough*
Chlorinating Equipment.—*Wallace & Tiernan*

Air Compressors
Two high pressure, for soot blowing air at 500 psig.—*FMA/Pokorny*
Two low pressure, for control air at 100 psi.—*Broom & Wade*

Boiler Feed Pumps
Capacity 220 tons per hr; 3220 ft.
Four.—*Sulzer*
Two.—*Stork*

Deaerators
Vertical, direct-contact type designed by *Cochrane* (Fr), built by *Tankfabriek.*

Valves
High pressure.—*Babcockwerke*
Low pressure.—*Erhard, J. Cocard, "Holland Boz" and Schönebecker Brunnenfilter*

Pipe Lines—*Ned. Electrolas Mij.*

Miscellaneous
Speed changers (1470–2980 rpm), for pump drive.—*Rademaker*
Four slip-ring motors (1250 hp, 1470 rpm) for pump drive.—*Heemaf*
Four Liquidrotor controllers.—*Allen West*
Two Squirrel-cage motors (1300 hp, 2980 rpm).—*Heemaf*
Boilers erected by *Kon. Mij. "De Schelde"*

Electrical Equipment
Transformers:
2–70,000 WA, 10.4/150 kv.—*Savoysienne*
3–4000 VA, 10/3 kv.—*English Electric*
4—1000 VA, 10,000/330 v.—*Smit*

Motors
Suirrel-cage and slip-ring motors.—*Heemaf; EMF Dordt and B.B.C.*
Commutator motors.—*EMF Dort*

Switchgear
High-tension metal-clad, 10 kv and 3 kv.—*Reyrolle*
Low-tension metal-clad, 380 v.—*Hazemeyer*
Low-tension switches.—*Heemaf, B.B.C., Hazemeyer*

*Methods of Steam Temperature Control on Large Power Boilers**

By GORDON R. HAHN

Division Engineer, Consolidated Edison Co. of New York, Inc.

The importance of steam temperature control for large power boilers is widely recognized. This paper presents some of the fundamentals and takes into consideration the significance of maintaining close control, the manner in which steam temperature varies with load, some of the principal control methods used, and recent applications at the East River and Astoria Stations of the author's company.

TECHNOLOGICAL progress in metallurgy has made possible the increase of superheated steam temperatures to the present levels of 1050 and 1100 F. Accurate regulation of these temperatures is extremely essential to avoid overstressing of materials and loss of station efficiency. As is characteristic of many engineering problems, there are a number of alternative solutions which the manufacturers of steam-generating equipment have found satisfactory for controlling steam temperature to meet specified conditions over wide-load ranges. It is the purpose of this paper to examine some fundamental considerations and show what techniques have been developed to insure maintenance of reasonably constant outlet steam conditions in modern central stations.

Importance of Steam Temperature Control

1. To maintain temperature at design value over a fairly wide-load range is essential for economy purposes. It is well understood from thermodynamic considerations that the higher the steam temperature, the higher the over-all cycle efficiency. Furthermore, the higher the temperature at the turbine throttle, the lower the moisture will be in the lower turbine stages. This is an important advantage because moisture causes an appreciable mechanical efficiency loss and erodes turbine blades. It may also further decrease efficiency and increase maintenance.

2. The turbine, superheater and reheater and all connecting piping are designed for certain specified temperatures. Prolonged or frequent exposure to higher temperatures will result in shorter life or may result in over-stressing or damaging tubes or turbine parts. Temperatures, therefore, should be controlled to keep them from exceeding their design limits.

3. The importance of superheat control is further augmented by the fact that as steam pressures and temperatures increase, a greater and greater percentage of the total heat liberated is absorbed in the superheater, as shown in Fig. 1.

Why the Steam Temperature Varies with Load

For economic reasons at design load the temperature of the gases leaving the furnace is as high as practical in keeping with slagging characteristics of the specified fuels. At lower loads the actual heat content of the gases leaving the furnace decreases and makes it difficult to get the desired steam temperature. If heat available per pound of fuel versus per cent load be plotted, it will be noted that there is a slight falling off in heat available as load decreases. Similarly, the heat content of the gas leaving the economizer also shows a slight drop. However, the heat content in the gas leaving the furnace will decrease appreciably, because the heat absorbing area in the furnace remains constant, and it thus extracts proportionally more heat at low loads than it will at full load. This leaves less heat to be absorbed in the convection surfaces, and the steam temperature drops off, as shown in Fig. 2.

Maintaining Steam Temperature Over a Wide Load Range

1. Location of Superheater

A convection superheater gives a rising temperature characteristic and a radiant superheater a falling characteristic. Combination of the two gives an approach to a flat characteristic (Fig. 3). This scheme has been used for years, specifically in bent-tube boilers where the super-

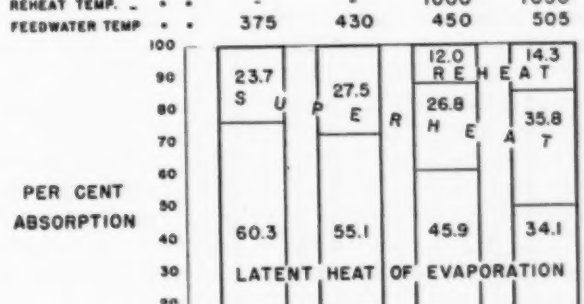


Fig. 1—Heat absorption in superheater and reheater as steam temperature and pressure are increased

* Adapted from an address under the sponsorship of the Industrial Instruments and Regulators Division of the ASME Metropolitan Section and presented on February 26, 1952. Other speakers on the same program amplified the fundamentals presented in this paper by providing reports on actual operating experience in central stations of several utility systems.

heater is nestled within the first bank of steam-generating tubes. The superheater partially sees the furnace and absorbs heat by both radiation from the furnace and convection from the gases. A combination of superheaters, one serving as a furnace wall and the other a convection bank is also used to give a flat characteristic.

2. Oversurfacing With Either Desuperheating or Gas By-passing at High Loads

Since a convection superheater characteristic is rising, it is possible to design the superheater to give design temperature at some partial load and at loads above this partial load to eliminate the temperature rise above design by allowing some of the gases to bypass the superheater. Suitable dampers control the gas flow to maintain design temperature, as illustrated in Fig. 4.

As an alternate to bypassing, the superheater may be built in two sections with a water spray, or attemperator,

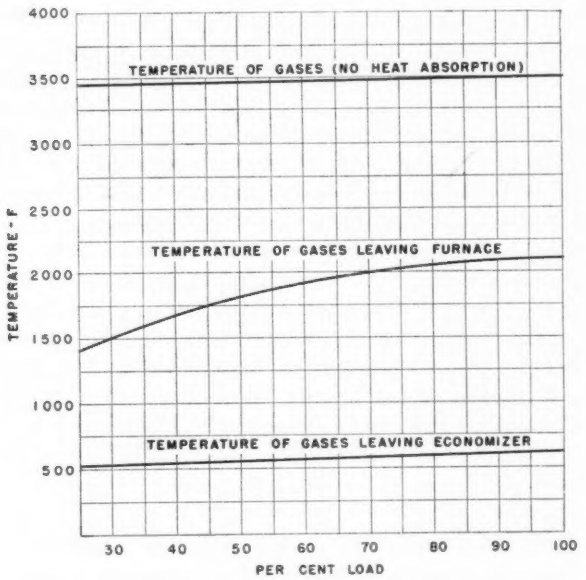


Fig. 2—Curves showing relationship of load to temperatures at various locations in a large steam-generating unit

between the sections cutting down the outlet steam temperature to a desired value.

3. Burner Tilt

Another means of varying the steam temperature is to change the temperature of the gases leaving the furnace. This can be done by the so-called "burner tilt" method in which the furnace wall area subjected to direct radiation and convection is changed by varying the burner nozzle position in the vertical plane from, say, 25 deg above horizontal to 25 deg below horizontal. With the burners upwardly inclined the lower furnace wall section is relatively ineffective in absorbing heat and hence the furnace outlet temperature rises. Conversely, operating with the burners below horizontal increases the effective wall-absorbing surface and furnace gas outlet temperature goes down, followed by the steam temperature (Fig. 5).

4. Temperature Control by Burner Selection

Some boilers are equipped with burners at several elevations in one wall. If only a portion of the burners are needed for fractional-load operation, it is possible by selection of burners to raise or lower the resultant flame

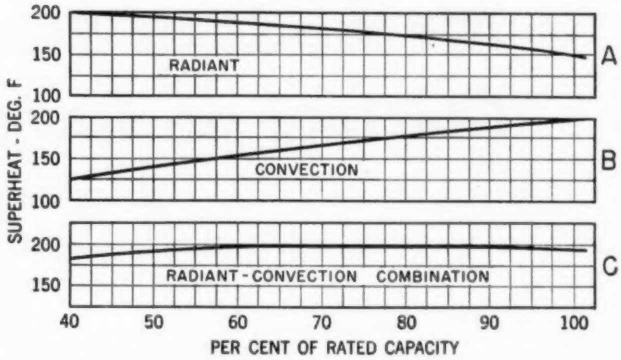


Fig. 3—Performance characteristic for combination radiant and convection superheaters

by several feet, depending on whether the bottom or top burners are out of use. This will raise or lower the steam temperature in a manner somewhat similar to burner tilt.

5. Dirty Walls

Still another method of steam temperature control, whether premeditated in the design or not, is to allow the furnace walls to dirty up until the desired steam temperature is reached. This can then be maintained by judicious wall soot blowing.

Even though a boiler does have wall soot blowers and walls obligingly slag, this method is not particularly recommended as a permanent means of control since it purposely increases the temperature of the gases leaving the furnace. This results in a higher boiler outlet temperature with attendant efficiency loss and a dirtier superheater, due to the higher entering gas temperature.

6. Superheater Condenser Method

The superheater condenser method uses some of the feedwater on its way to the drum to extract heat from the saturated steam by means of a heat-exchanger in the saturated steam-collecting heater. Varying the quantity of feedwater in the two parallel paths, one through the economizer and the other through the superheater condenser, makes it possible to maintain the desired outlet steam temperature, as shown in Fig. 6.

7. Gas Recirculation

Gas recirculation methods of steam temperature regulation introduce flue gases withdrawn from the economizer outlet either into the main air duct ahead of the burners or directly into the lower portion of the furnace. The recirculated gas addition has the effect of decreasing the maximum furnace temperature due to changed combustion conditions in the first instance and blanket-

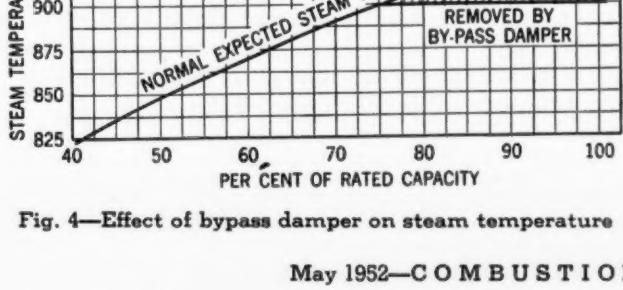


Fig. 4—Effect of bypass damper on steam temperature

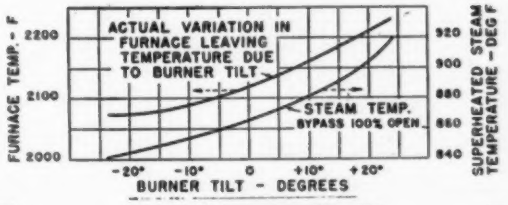
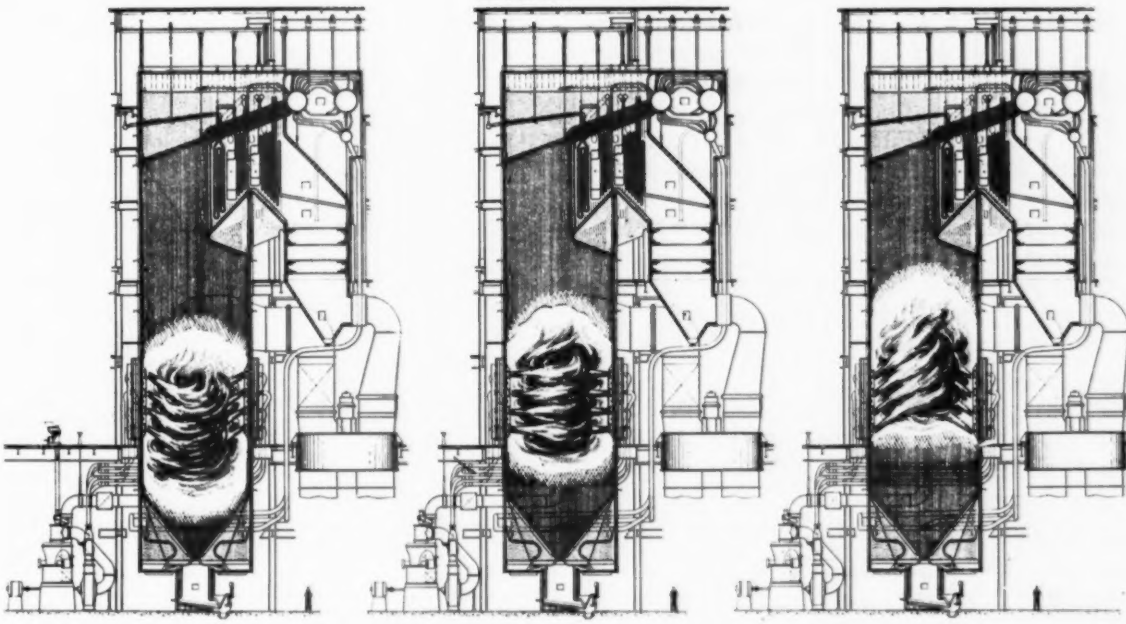


Fig. 5—Effect of tilting burners on steam temperature



ing furnace wall area in the second instance, both resulting in a reduction in the amount of heat absorption by the furnace walls. This leaves a greater heat content in the gases flowing from the furnace outlet to the convection superheater, particularly because of the greater gas weight. The greater heat content provides more heat to the convection superheater and thereby raises the final superheat temperature.

Depending upon factors such as the geometry of the furnace, manner of recirculated gas introduction, extent of wall cooling and rate of recirculation, the temperature of the gases leaving the furnace may be raised slightly or lowered by the recirculated gas addition.

While a rise in furnace outlet gas temperature may occur at lower load rates depending upon the factors mentioned, there will be no rise in outlet temperature conducive to an increase in slagging at maximum load, because little, if any, gas will be recirculated at that load.

8. Separately Fired Superheaters

In some instances steam generating units are designed with two furnaces with (*a*) more superheater surface

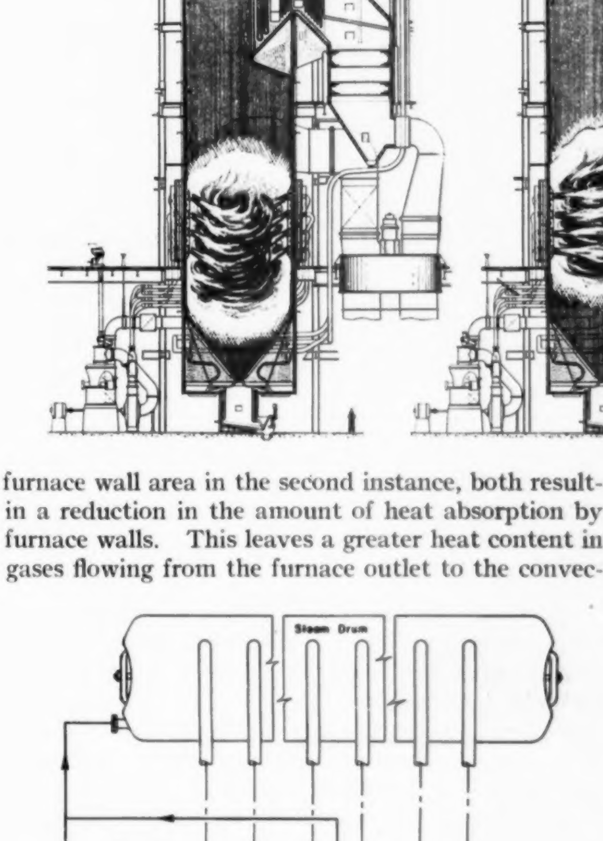


Fig. 6—Superheater condenser method of controlling steam temperature

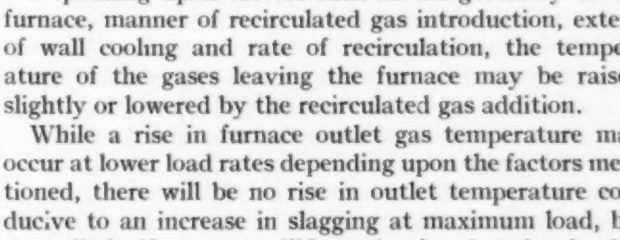


Fig. 7—Steam temperature control with combination radiant superheater and convection reheater

following one than the other, or, (*b*) a radiant superheater which may be incorporated in one of the furnaces. With this sort of an arrangement the steam temperature may be varied by varying the fuel fired in the two furnaces.

Current Applications on Consolidated Edison System

1. East River No. 70 Boiler Temperature Control

This Foster-Wheeler boiler is designed for 1800 psi, 1000 F–1000 F reheat and has a radiant superheater comprising one furnace wall. The main steam temperature characteristic is very flat because of the combination of radiant and convection surfaces. The superheater condenser temperature control effects constant main steam temperature over a wide load range.

The reheater is of the convection type and the reheater outlet temperature if uncontrolled would vary over a wide range. To keep the reheater outlet temperature at its design value a bypass section is arranged to vary the amount of gas passing the reheater; see Figs. 7 and 8.

2. Astoria 10 and 20 Boilers

In the projected Astoria steam station, the B. & W. reheat boilers, which are designed for 1800 psi, 1000 F–1000 F reheat, incorporate several methods of temperature control to maintain the desired steam conditions. These are shown in Fig. 9 and include:

a. Gas recirculation will raise and lower the general steam and reheat outlet temperature level but the recirculation is controlled to regulate the main steam temperature to 1000 F.

b. The reheat temperature is matched to the main steam temperature by manipulation of dampers which control the relative flows through the primary superheater and reheater.

c. Spray-type attemperators between the primary and secondary superheaters, which are rarely expected to be used, limit main steam to 1000 F.

d. These boilers will have burners on four elevations in one wall—the top row for oil burning only; the center two rows are for coal, oil and gas; and the lower row for coal and gas only. Thus when burning oil the resultant flame is about 10 ft higher in the furnace than when burning coal or gas.

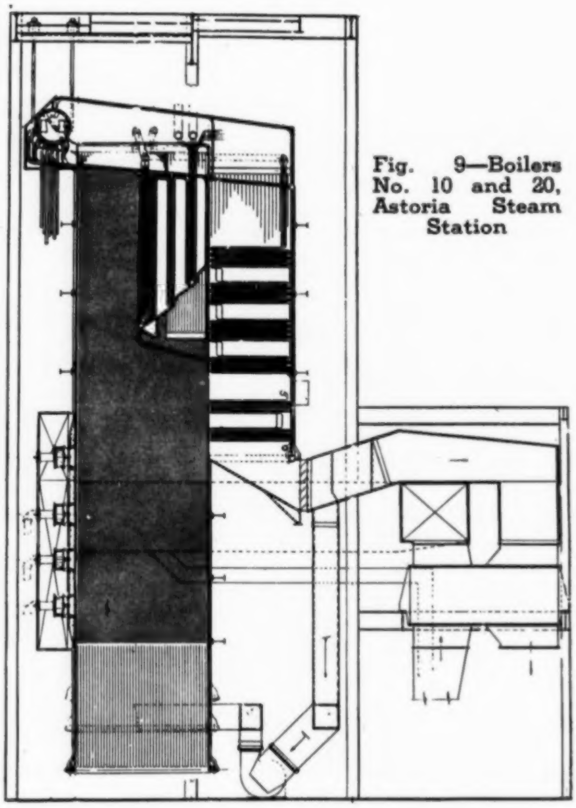


Fig. 9—Boilers No. 10 and 20, Astoria Steam Station

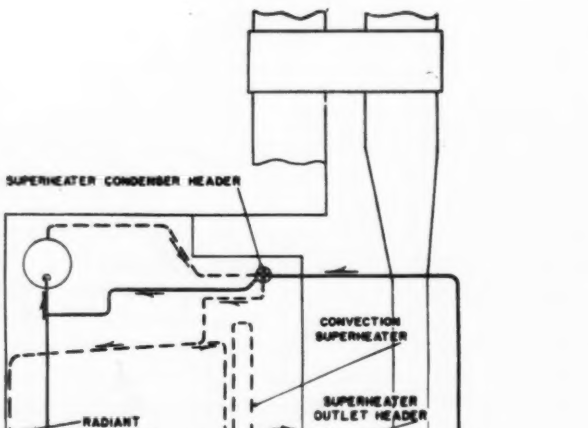


Fig. 8—East River temperature control, No. 70 boiler

Applications of Natural Steam in Italy

THE cover photograph of this issue represents one of the numerous natural-steam wells at Larderello, Italy, and the accompanying photographs show typical applications in a chemical plant and in a large central electric generating station. These were made available through the courtesy of the National Supply Company of Pittsburgh which is associated with the later deep-well drillings that are now being carried on.

This steam, presumably of volcanic origin, is projected in a continuous stream from fissures in the earth at various pressures ranging from 50 to 400 psig and at temperatures of about 435 F, in many cases in a superheated condition. The numerous existing wells are within an area of about 75 sq miles in the vicinity of Larderello. The largest, No. 82, which was brought in last July, produces 660,000 lb of steam per hour at 100 psig and 437 F. While the depths of present wells range up to 2000 ft, drillings are now in progress which involve much greater depths, through use of modern rotary drills.

Entrained with the steam are various gases such as carbon dioxide, hydrogen sulfide, methane and hydrogen; also ammonia and boric acid from which chemical plants extract ammonium carbonate, boron carbide and borax. Boric acid is the most important product.

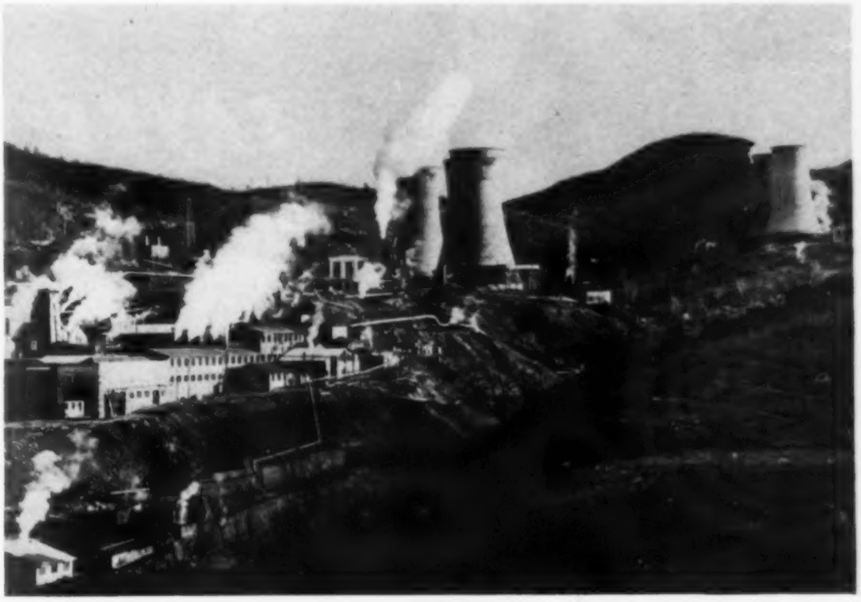
Several central power stations are supplied with such steam involving a total combined capacity of more than 250,000 kw, the largest containing four 30,000-kva turbine-generators.

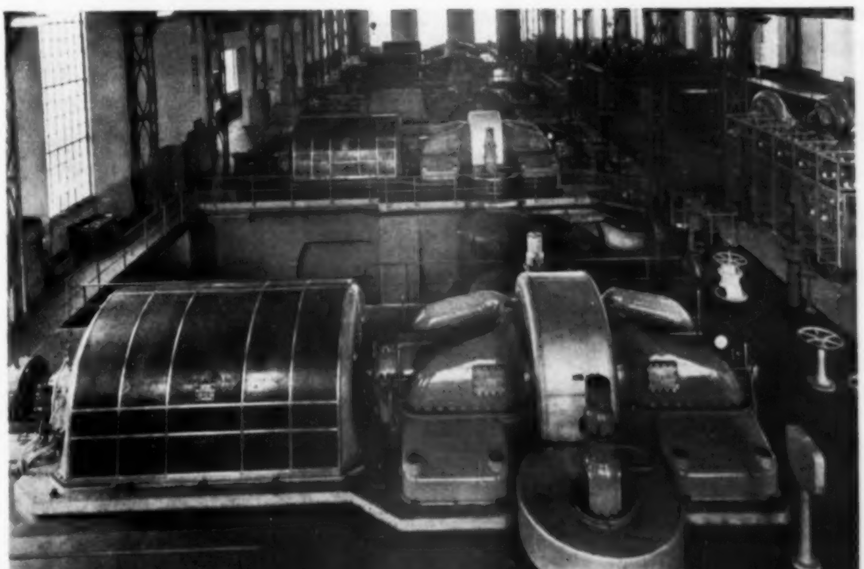
Relatively large turbo-compressors are necessary for extracting the gases. Since these steam wells, or fumaroles, are located where water supply is limited, large natural-draft cooling towers are employed in connection with the condensing turbine-generators. In some of the industrial plants non-condensing turbines are employed and the exhaust is used for evaporating the boric waters. Also, certain plants, instead of using the steam direct in the turbines, first pass it through a heat-exchanger and the pure steam is then passed to the turbines.

Most of these natural steam power stations, both central stations and industrial plants, were badly damaged by bombing or as part of the German plan of destruction when forced to retreat during the war, but these have since been rebuilt and more capacity added.

An extensive paper on the Larderello natural steam plants was presented about a year ago before the ASME at Atlanta.

One of several chemical plants operating with natural steam. Although steam is plentiful, water is scarce; hence the need for large natural-draft cooling towers





Turbine room of Larderello power station No. 3 which contains four 30,000-kva units operating at 68 psia and 437 F; compressors may be seen at right

View of Jones Street Station taken at crest of recent flood of the Missouri River

Burning Furfural Residue on Spreader Stokers

Furfural, a widely used chemical solvent, is a by-product of cereal manufacture and the residue of its extraction process is supplied by The Quaker Oats Company to the Jones Street Station of the Omaha Public Power District, where it is burned on a spreader stoker. In exchange, low-pressure steam, electricity, treated water, and cooling water are supplied by the power plant to the industrial plant nearly half a mile distant.

IN the milling operations involving grains, such as corn, rice, oats and wheat, there remain the hulls, husks, corn cobs, etc., which at one time presented quite a disposal problem. Later there developed wide and important uses for the cellulose product, furfural, which they contain, and the demand became such as to warrant construction of plants specifically for its extraction. One such plant is that of the Quaker Oats Company at Omaha, Nebraska.

The furfural is extracted as an amber-colored liquid by digesting the accumulation of husks, corn cobs, etc., with steam in huge vats. Among its uses are as a chemical solvent in the manufacture of nylon, synthetic rubber and certain plastics; also in the refining of lubricating oils. The residue from the extraction process resembles coffee grounds and contains 30 to 40 per cent moisture and about 2.5 per cent ash. It runs relatively high in sulfuric acid and analyzes about 5400 Btu per lb (wet).

This residue has value as a filler for fertilizer and is so employed in at least one locality, but the supply exceeds the demand and makes its use as fuel attractive.

Cooperative Agreement

The new Quaker Oats plant at Omaha is devoted entirely to the production of furfural, which is shipped in tank cars to customers, principally the du Pont Company. Instead of installing a power plant which could not have used all the available residue as fuel, a 20-yr cooperative agreement was made with the Omaha Public Power District, by which the latter would supply steam and water for process from its Jones Street Station and the former would supply the furfural residue as fuel for one of the power station's boilers.

This station is located along the Missouri River some 2200 ft from the Quaker Oats plant. The residue, of which some 25 tons per hour will be available when the plant is running at full capacity, is blown through two 10-in. lines to the power plant. The latter, in turn, supplies electricity and exhaust steam from a 10,000-kw topping turbine-generator, through a reducing valve, at 125 psig through an 18-in. line, as well as both treated and river water. In reverse order, some low-pressure steam at 25 psi is returned to the power plant for heating feedwater. Thus an economic arrangement is effected.

Furfural residue is the base fuel for this steam-generating unit with coal or natural gas as supplemental fuels, the latter being available principally during the warmer months when the heating demand in the region slackens.

The boiler in which this residue is burned is a 265,000-lb per hr, 1225-psig, 910-F Combustion Engineering unit installed in 1936 to furnish steam to a 10,000-kw topping turbine. It was formerly equipped with a chain-grate stoker. In order to adapt it to the new fuel conditions, considerable reconstruction was necessary, including a complete change in the contour and arrangement to provide a furnace adaptable to spreader-stoker firing. The throat of the furnace was eliminated by removal of both the front and rear arches and the volume was practically doubled. The water walls were reconstructed by placing 3-in. fin tubes on all walls, the fin type on $5^1/_8$-in. centers being dictated by the necessity for a number of openings for overfire air nozzles and soot blowers. The existing superheater was replaced by a two-stage pendant type with interstage desuperheating, other changes being made in the screen tubes in front of the superheater and in the slope of the furnace roof.

The chain-grate stoker was replaced by one of the key-and-bar type measuring 23 ft, 6 in. by 25 ft, and at each of two levels at the front wall were installed sets of six 24-in. spreader-stoker distributors, the lower for burning coal and the upper for furfural residue. Their location will be noted on the cross-section. The former employs underthrow distributors and the latter overthrow. At a level somewhat higher than the upper spreaders were placed tangential gas burners, two on each of the side walls.

The duct system was completely revamped and a single new induced-draft fan of American Blower design replaced the two former fans in order to simplify the control. Also, a larger forced-draft fan was installed in order to meet the greater amount of air required for burning the furfural residue. This delivers at a static pressure of 14 in. of water. Up to 50 per cent of the air for combustion may be supplied as overfire air by jets located in the front and rear walls. These take preheated air at 350 F from the forced-draft duct and deliver to the furnace at around 6-in. pressure. The remainder of the combustion air is supplied under the stoker when burning coal and residue and around the burners when burning natural gas.

A Buell cinder-collection system of the cyclone type was placed above the boiler ahead of the induced-draft fan. Collections in the hoppers under the boiler pass and the economizer are returned to the furnace for reburning and are introduced through the back wall just above the stoker.

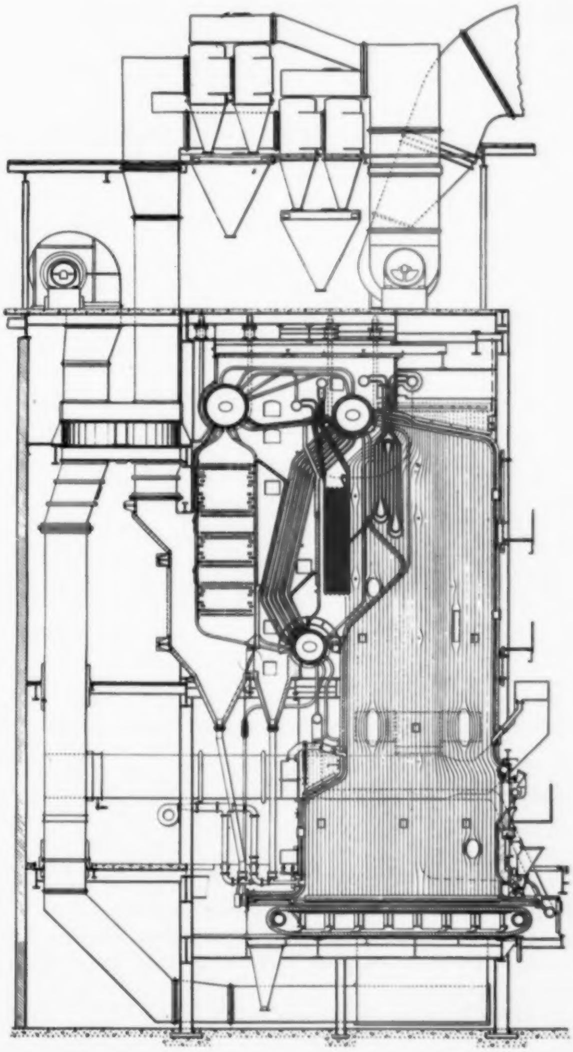
The bunker supplying the spreader hoppers is divided for coal and for furfural residue, and a housed belt conveyor is employed for handling. This, as well as the fur-

Omaha furfural plant of The Quaker Oats Company with reserve cob storage in center background

fural hoppers, are of stainless steel because of the acid character of this fuel. At the present time 15 to 18 tons of furfural residue are being burned per hour. Ashes are handled by a hydraulic sluicing system, which delivers to an outside storage bin for dewatering after which they are hauled away.

Operation

Since some of the residue falls to the grate and burns in mixture with the coal, an investigation was made as to ash fusion and softening temperatures with various per-



Section through steam generating unit showing rebuilt furnace

centages of coal and furfural residue, the coal being Kansas washed slack. This showed the highest ash fusion and softening temperatures (2500 F and 2350 F, respectively) to result with about 30 per cent coal and 70 per cent furfural residue.

During the early period of operation steam temperature was higher than anticipated because of long flame. This was caused by a lack of air penetration from the overfire air jets into the flame envelope, which is highly concentrated when all feeders are operating. Studies have been made to correct this condition by a redistribution of the overfire air.

Centrifugal Pumps in Steam Power Stations

By R. Pennington*

In a paper presented before The Institution of Mechanical Engineers, London, on March 21, 1952, the author discussed some of the fundamental and specific hydraulic considerations associated with the operation of centrifugal pumps. Attention is drawn to the importance of selecting the correct speed for reliable operation. Methods of operating extraction pumps on two types of surface condensers are shown.

CENTRIFUGAL pumps are employed for a wide range of services in steam power stations. Fig. 1 shows how they may be applied to the feed-water circuit between condenser and boiler, for forced circulation with the La Mont type of boiler, ash sluicing and quenching, ash conveying, sump drainage, silt removal from culverts, feedwater makeup, general service, transformer oil circulation, fire services and auxiliary oil circulation on main turbine-generator.

Notation

A_t = Atmospheric pressure
C_c = Cavitation coefficient
e = Pump efficiency
H = Net total head
h = Net head per stage
h_a = Net available head, per stage
h_{cm} = Cavitation margin
h_{dp} = Depression head
h_f = Friction losses before pump inlet
h_g = Generated no-loss pressure head
h_i = Absolute head at pump inlet
h_l = Total hydraulic losses in pump
h_s = Suction lift
h_{st} = Static head over pump center-line
L_i = Pump inlet size = $Q^{1/2}/h_{dp}^{1/4}$
N = Pump speed, rpm
n = Number of stages in pump
P_{pi} = A dimensionless parameter = V_i/U_i
Q = Output
S_e = Speed coefficient in formula: $N_{max} = S_e h_{dp}^{3/4}/Q^{1/2}$
S_h = Specific heat of liquid
U_i = Peripheral velocity of the impeller eye
V_i = Axial component of flow in impeller eye
V_p = Vapor pressure
W = Output, lb per hr
X = Balance leakage, lb per min

* Director, Messrs. Mather and Platt, Ltd., Manchester, England.

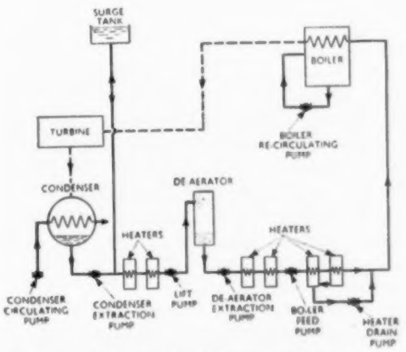


Fig. 1—Typical diagrammatic arrangement of centrifugal pumps in main flow circuits

Choice of Speed

One of the factors of primary importance that applies to all services is the fixing of the pump speed. The higher the speed the smaller the size of pump and the lower

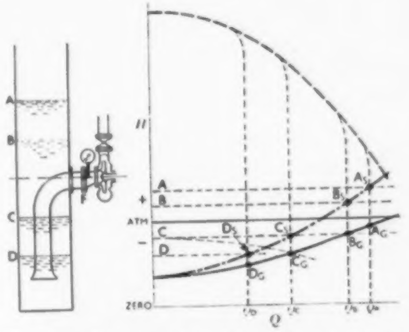


Fig. 2—Effect of inlet head on centrifugal pump performance

— — — — H/Q characteristic
– – – – – — Absolute static inlet head at pump center-line
———— Absolute head at pump inlet flange h_i (throttling curve)

the cost, but care must be taken not to sacrifice quality, efficiency or reliability. Excessive speed may mean cavitation trouble and resultant erosion, vaporization, loss of pressure or seizure. The following considerations show how the maximum safe speed can be determined.

THROTTLING. On the left-hand side of Fig. 2 a simple pump is shown drawing water from a tank in which the level can be varied above and below the pump center-line. The speed is assumed constant and the output is regulated on the discharge valve. At the highest inlet level A the H/Q characteristic, shown to the right, is obtained. A point is reached during the opening of the valve when the head breaks away from the normal curve and falls steeply at constant output, Q_A, corresponding to the absolute static inlet head A_S. If the inlet level is lowered to B the maximum output is reduced to Q_B. Similarly for the lower levels, C and D, outputs are limited to Q_C and Q_D. The curve passing through points A_S, B_S, C_S, D_S represents the absolute head at the pump center-line under static conditions, while the lower curve passing through points A_G, B_G, C_G, D_G shows the corresponding absolute head at inlet, h_i, under flow conditions as measured by a gauge at F. This latter curve is usually known as the "throttling" curve.

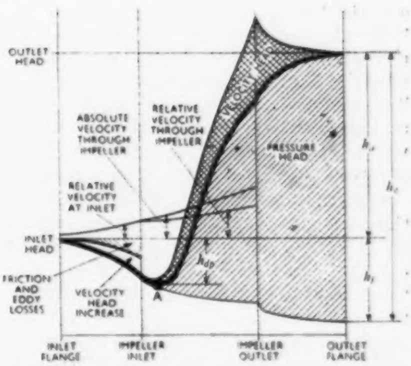


Fig. 3—Hydraulic gradient through centrifugal pump showing depression head

HYDRAULIC GRADIENT AND DEPRESSION HEAD. Fig. 3 shows how average pressures and velocities vary through a centrifugal pump operating at constant speed and constant output. The curves, not to scale, are merely intended to convey a general picture of the changes that occur in the pump. The bottom curve shows the hydraulic losses, h_l, between inlet and outlet flanges while the diagonally shaded area represents the generated no-loss pressure head, h_g. The cross-hatched area is the velocity head, most of which is converted to pressure in the casing, and so the heavy full line represents the hydraulic pressure gradient. h_a is the net available head. The region of minimum pressure at point A lies just beyond the inlet edge of the impeller vanes, and the fall in pressure between the inlet flange and point A may be termed the "depression head," h_{dp}. It will be noted that the depression head is

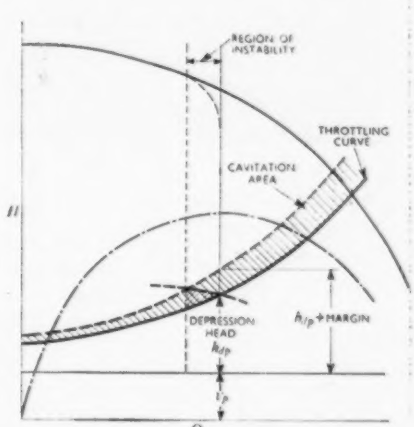


Fig. 4—Cavitation area for centrifugal pump

———— Absolute head at pump inlet flange h_i (throttling curve)
———— Head
— — — — Efficiency
Cavitation area shown shaded

slightly less than the total value of the hydraulic losses at that point, due to the partial generation of head that has occurred. A pump throttles when the absolute pressure at A is equal to the vapor pressure of the liquid, or, in other words, when the inlet head, h_i, is equal to the depression head plus the vapor pressure.

Cavitation Area. In Fig. 4 the throttling curve shown in Fig. 2 is reproduced as a heavy, full line representing vapor pressure plus depression head. Under these conditions the pump is operating at the maximum possible speed for a given output corresponding to the inlet head shown on the curve. If the pump is taking its supply from a closed vessel with the liquid at saturation pressure and temperature it will operate satisfactorily with a head at the inlet flange equal to the depression head plus vapor pressure (that is to say, on the throttling curve) provided that the liquid in the supply vessel is allowed to fall freely to its natural level. If the level is controlled, provision of an adequate margin in inlet head is important if cavitation is to be avoided. The dangerous cavitation area is shown shaded, and it will be noted that it corresponds to the unstable region of the head–output characteristic.

Speed Coefficient. A relation can be established between output, depression head, size of pump at inlet and maximum permissible speed. For a range of pumps geometrically similar on the inlet side and operating under conditions of dynamic similarity at inlet, ND_i is constant, where N is the pump speed, and D_i is the linear size at inlet, which may be expressed conviently by the impeller eye diameter.

Also $Q \propto D_i^3$, and therefore $Q^{1/3} \propto D_i$, so

$$NQ^{1/3} \text{ is constant} \qquad (1)$$

For a given size of pump, if the speed is changed and the pump is operating at all times on the throttling point, that is, at the maximum possible speed for a given output and inlet head, then it is found that $h_{dp} \propto N_{max}^2$ (providing $Q \propto N_{max}$).

Or

$$h_{dp}^{1/2} \propto N_{max} \qquad (2)$$

Also as $Q \propto N_{max}$, and therefore $Q \propto h_{dp}^{1/2}$, or

$$Q^{1/2} \propto h_{dp}^{1/4}. \qquad (3)$$

It follows from equations (2) and (3) that:

$$N_{max}Q^{1/2} = \text{constant} \times h_{dp}^{3/4} \qquad (4)$$

From equations (1) and (4) it would appear that for a range of similar pumps of varying size h_{dp} must be constant. However, owing to the "size effect" the larger the pump the smaller is the value of h_{dp} for a constant value of $N_{max}Q^{1/3}$. Thus the relation becomes:

$$N_{max}Q^{1/2} = \text{coefficient} \times h_{dp}^{3/4} \qquad (5)$$

or

$$N_{max} = S_c \frac{h_{dp}^{3/4}}{Q^{1/2}} \qquad (6)$$

where S_c may be termed the speed coefficient.

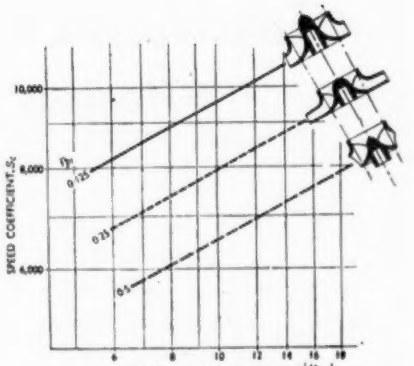


Fig. 5—Relation between speed coefficient and inlet size

Single-inlet impellers; for a double-inlet impeller take half the output when evaluating N_{max} and L_i.

$N_{max} = S_c(h_{dp}^{3/4}/Q^{1/2})$

———— Highest speed
- - - - - - Highest efficiency
— — — — Highest specific speed

Values for Q are Imperial gallons per minute

The value of S_c depends not only on pump size but also on type of design, and is influenced to a lesser extent by net total head, efficiency and specific gravity of liquid (the last three factors affect the diameter of the impeller hub).

Inlet Parameter. The principal design factor controlling the value of S_c is the ratio between the axial component of flow in the impeller eye and the peripheral velocity of the eye, which may be expressed as a dimensionless parameter:

$$P_{pi} = V_i/U_i$$

Fig. 5 shows values of S_c for various values of P_{pi} plotted against inlet size, which may be expressed hydraulically as $L_i = Q^{1/2}/h_{dp}^{1/4}$. For calculating L_i and N_{max}, values of Q are for single-inlet impellers; for double-inlet impellers take half the total output. As P_{pi} is reduced, S_c increases up to a peak value for a given size as shown in this diagram. It is also seen how S_c increases with an increase in hydraulic inlet size. Low values of P_{pi} usually involve a sacrifice in efficiency, and would normally be used for low values of depression head (that is, where inlet heads are low) in order to obtain a reasonably high speed.

Effect of Net Head per Stage on N_{max}. The maximum permissible speed to suit the output and inlet head having been determined, it is necessary to investigate whether that speed is suitable for the net head per stage. The two upper impellers in Fig. 5 are designed for the same depression head in relation to net total head, and it is seen that as P_{pi} is reduced, the impeller inlet diameter is increased and the outlet diameter reduced. If the depression head is increased (thus increasing N_{max} and therefore the specific speed) or if the net head is reduced (which also increases the specific speed) a point is reached when there is insufficient vane length to enable a satisfactory design of impeller to be developed, and the lower the P_{pi} value the earlier that limit is reached.

Condenser Circulating-Water Pumps.

It is usual to design a condenser circulating-water pump for a normal suction lift of 15 feet. If the pump is to run at the highest practicable speed then it will operate just outside the cavitation area (Fig. 6). In terms of suction lift:

The depression head $h_{dp} = C_c(A_t - V_p - h_s)$ where A_t is the atmospheric pressure in feet; V_p the vapor pressure in feet; h_s the suction lift in feet; and C_c the cavitation coefficient.

This cavitation coefficient $C_c = h_{dp}/h_{dp}+$cavitation margin, and its value may be taken as 0.8.

Thus for a suction lift of 15 ft and 75 F:

$$h_{dp} = 0.8(34-1-15) = 14.4 \text{ feet}$$

For this service high efficiency is important, requiring a P_{pt} value of about 0.25 (Fig. 5). For the usual range of capacities an approximate average value

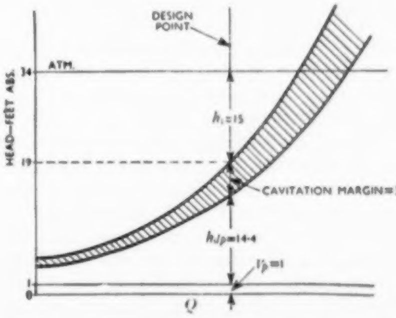


Fig. 6—Relation between depression head and suction lift

Assuming 15 feet suction lift at 75 F. Cavitation area shown shaded

for the speed coefficient, S_c, for pumps of normal design with double-inlet impellers is 9450.

Thus

$$N_{\max} = S_c\frac{h_{dp}^{3/4}}{Q^{1/2}} = \frac{9450 \times 14.4^{3/4}}{Q^{1/2}} = \frac{70{,}000}{Q^{1/2}}$$

where Q is in Imperial gallons per minute (I.G.P.M.) and half the total output for a double-inlet impeller.

Condensate-Extraction Pumps

Extraction pumps have to be designed to operate satisfactorily with a very small inlet head above the pump center-line and with the water at the saturation temperature corresponding to the vacuum in the condenser. Every few inches additional head required by the pump may involve a corresponding increase in the height of the power station building, with a resultant increase in cost.

As the water is at boiling point, care must be taken in the design of the pump and in the arrangement relative to the condenser to avoid cavitation when operating with such restricted inlet heads.

There are two main types of surface condenser: the free-level type and the controlled-level type.

Free-Level Condenser. On the free-level type of condenser (Fig. 7) the extraction pump withdraws condensate at the same rate as the rate of condensation at all loads. The water-level in the condenser increases as the load increases, but remains steady at constant load. The exact relation between the water-level and the load is a function of the design of pump and the frictional losses between the pump and the condenser.

If the demand at the boilers is at any time less than the rate of condensation in the condenser, then the surplus is discharged into the surge tank. Conversely, if the boiler demand exceeds the rate of flow into the condenser (and therefore the rate of pumping) the balance of requirements is drawn automatically from the surge-tank. A pump operating under these conditions is running on the "throttling" point at all loads. In effect, the pump acts as an automatic regulating valve and takes all that comes to it.

It has already been shown that when a pump is "throttling," the pressure head at the inlet flange (corrected to the pump center-line) is equal to the vapor pressure at the working temperature plus the "depression head." With a surface condenser the vapor pressure is the pressure in the condenser immediately above the water-level. It follows that the "depression head" must be provided by the static height of the water in the condenser above the pump center-line. This static head must also provide for the frictional and other losses between the condenser and pump, but these losses are usually small

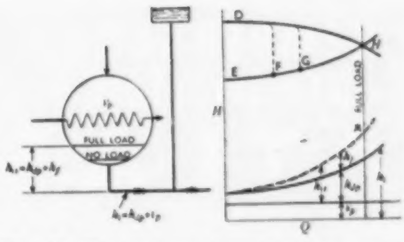


Fig. 7—Operation of extraction pump on free-level condenser

A = Static inlet head plus vapor pressure
D = Pump head characteristic
E = System characteristic
F, G = Typical operating points

on account of the very low velocities employed.

If h_{st} is static head over pump center-line, h_i absolute pressure head at pump inlet flange, h_f friction losses at inlet side, and V_p vapor pressure, then

$$h_i \text{ (required)} = h_{dp} + V_p \text{ (when "throttling")}$$

Also

$$h_i \text{ (available)} = h_{st} - h_f + V_p$$

Therefore,

$$h_{st} = h_{dp} + h_f$$

This establishes the relation between the inlet static head and the "depression head" of the pump.

A condensate pump is required to operate at any output, from full load to very light load, and when drawing from a free-level condenser the pump automatically

follows all changes in load. With each change in load the water-level in the condenser takes up a new position in accordance with a curve, such as A, shown in Fig. 7, where $h_{st} = A - C$, and $C = V_p$.

The normal net head characteristic is shown by curve D. The pump outlet is not restricted in any way and is open at all times to the surge-tank. Thus the discharge head is equal to the static head of the tank plus pipe and valve friction. Under ordinary pumping conditions the pump would discharge at a constant rate H where the pump characteristic D intercepts the system characteristic E, but on extraction duty for two typical rates of discharge F and G the heads must lie on the system characteristic E. Thus the pump follows the system characteristic, and the difference in head between curves D and E is dissipated in the pump casing around the impeller.

A pump operating in this manner is said to be working on the cavitation limit, and it is sometimes thought that this is a dangerous procedure and likely to result in pitting and erosion of impeller and casing. Long experience has shown, however, that a correctly designed and installed pump may operate under these conditions indefinitely, suffering no damage and not requiring special materials.

CONTROLLED-LEVEL CONDENSER. On the controlled-level type of condenser the water level is maintained between definite and close limits by a float-controlled three-way valve. If the draw-off to the boilers exceeds the rate of condensation in the condenser, the water level falls slightly, and the ball-float-operated valve admits make-up water to the condenser from the surge-tank. When the supply to the boilers is less than the rate of condensation, the rise in level, through the operation of the valve, permits the surplus water to be discharged from the pump direct to the surge-tank.

For steady-load conditions, at any load, where the boiler demand equals the rate of condensation, there is no flow either into or out of the surge-tank and the level in the condenser remains in the mean position.

The operating characteristics shown in Fig. 8, differ in many ways from those for a free-level condenser. It has already been shown that an extraction pump can operate quite safely on the "cavitation limit" inlet-head curve B. The possibility of trouble arises, however, when the inlet head is artificially maintained above this curve, and to ensure freedom from cavitation trouble it is essential to provide a minimum margin as shown by curve B_1. The shaded area between curves B and B_1 is the dangerous "cavitation area" and must be carefully avoided.

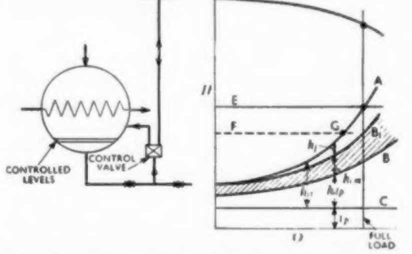


Fig. 8—Operation of extraction pump on controlled-level condenser

A = Static inlet head plus vapor pressure
$A-C = h_{st}$ = minimum static head over pump inlet for varying outputs
B = Cavitation limit inlet-head curve
$B_1 - B$ = Cavitation margin or cavitation area
$E-C$ = Minimum safe static inlet head
D = Normal pump head characteristic

Allowing for pipe friction, etc., the curve A is established, and the minimum required static head over the pump inlet is $h_{st} = A - C$. As the water level is maintained approximately constant, it must be arranged to suit maximum load conditions as shown by line E, if trouble is to be avoided. If the level is arranged lower than this, as sometimes happens, say, at F, then satisfactory operation would take place at all loads up to G, but beyond this point the pump would be operating in the dangerous "cavitation area."

Thus the minimum static inlet head

$$h_{st} = h_{dp} + h_{cm} + h_f$$

where h_{cm} = cavitation margin = $E-C$ (based on full-load conditions).

As the rate of pumping is not controlled by the level in the condenser, and as the outlet is not freely open to the surge-tank it is obvious that the rate of output at any given moment is determined by the amount of restriction on the discharge side. Therefore the net head characteristic follows the normal pump characteristic as shown at D.

DEAERATOR EXTRACTION PUMP. The feedwater is sprayed into the steam space of the deaerator and is drawn from the bottom of the vessel by the deaerator extraction pump, as shown in Fig. 9. The steam supply to the deaerator is usually taken from one of the stages of the main turbine, and therefore the temperature and pressure will vary with the load on the turbogenerator. The conditions may vary from, say, 28 inches vacuum to 25 psig and between the corresponding temperatures 80 and 250 F.

Apart from the variation in temperature and corresponding variation in inlet pressure, the operation of a deaerator extraction pump is generally similar to that of a condenser extraction pump, controlled-level type.

The vapor pressure above the water-level in the deaerator (and the corresponding water temperature) vary with the load on the main unit, and correspond with the inlet-steam pressure and saturation temperature. The curves in Fig. 9 show the inlet-head characteristics under these varying conditions.

C_{p1} represents the lowest vapor pressure and V_{p2} represents the highest vapor pressure. The depression head, cavitation area and frictional head are constant for all conditions of temperature and pressure. Therefore the minimum static inlet-head to avoid cavitation is constant at all loads, that is, $h_{st1} = h_{st2}$.

It is sometimes advisable to elevate the deaerator at a sufficient height above the pump to ensure adequate margin in head above the minimum permissible figure, to provide a safeguard against the possibility

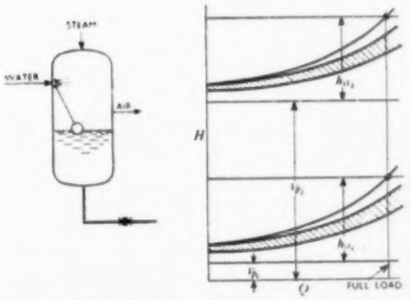


Fig. 9—Operation of deaerator extraction pump

of trouble due to a sudden fall in deaerator pressure.

FACTORS INFLUENCING CHOICE OF SPEED FOR EXTRACTION PUMPS. For extration pumps of all types, namely, condenser extraction (free-level and controlled-level) and deaerator extraction, the same speed-output relation holds good as for circulating pumps, that is, $N_{max} = S_c h_{dp}^{3/4}/Q^{1/2}$.

However, it will be clear that extraction pumps must be designed for very low values of "depression head" on account of the low inlet-heads available, particularly on condensers. These low depression heads would give very low values of speed for any given output if best efficiency values were taken for P_{pt}. Also, the average outputs for extraction pumps are small compared with the outputs for circulating pumps, and the value of the speed coefficient falls as the size of pump is reduced. Thus it is usually found advisable to sacrifice efficiency to some extent, to obtain a reasonably high speed, by the use of an impeller having a lower P_{pt} value.

The highest value of the speed coefficient for the average size of extraction pump may be taken as approximately 8500.

Boiler Feed Pumps

PRESSURE CHARACTERISTICS OF THE FEED SYSTEM. The curves in Fig. 10

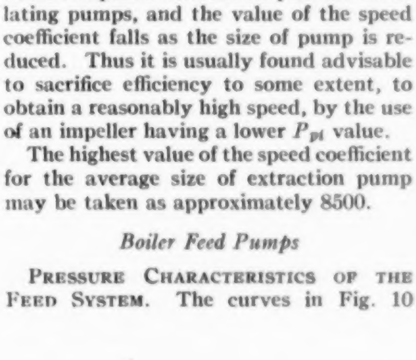


Fig. 10—Pressure characteristics of boiler feed system

——— Pressure required at pump outlet; *A*, normal maximum, *B*, minimum, *C*, blow-off

— — — Boiler drum pressure; *D*, blow-off, *E*, normal maximum, *F*, normal minimum, or turbine stop valve pressure

illustrate the pressures required by the feed system at various steam and water flow-rates. The curves are based on a typical turbine stop-valve pressure of 1500 psig. To this figure must be added the frictional losses of the steam in the pipework to the turbine and in the superheater as shown. This fixes the maximum boiler-drum pressure for normal full load steam rating of the boiler. If to this be added the losses through the economizer, feed regulator and feed piping, and the static lift from feed pump to boiler drum, the pressure required at the feed-pump outlet is obtained. Feed-pump capacity is usually specified to be about 25 per cent in excess of boiler full load. Although average rates of steaming and feeding are equal over a period, there may be considerable divergence in the two rates at any given moment, and for that reason the feed pressure required for maximum steam rate follows curve A. Simi-

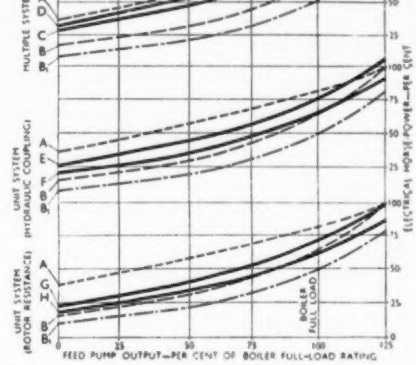


Fig. 11—Feed-pump power characteristics with variable speed

- A = Constant speed
- B = Variable-speed, ideal, maximum drum pressure
- B_1 = Variable-speed, ideal, minimum drum pressure
- C = Variable-speed, rotor resistance, multiple system
- D = Variable-speed, hydraulic coupling, multiple system
- E = Variable-speed, hydraulic coupling, maximum-drum pressure, unit system
- F = Variable-speed, hydraulic coupling, minimum drum pressure, unit system
- G = Variable-speed, rotor resistance, maximum drum pressure, unit system
- H = Variable-speed, rotor resistance minimum drum presure, unit system

larly, curve B represents the feed pressure required for minimum steam rate. Thus normal operating conditions may require any pressure and output between these two lines. Under blow-off conditions there is a considerable rise in boiler-drum pressure and the feed pressure required follows curve C, although it is usual to limit the pump output required under these conditions to suit approximately full-load boiler rating.

There is a tendency to be over-liberal in estimating the various losses in the system for normal operation, and this either involves the removal of pump stages or an

(Continued on page 70)

Tests of a 4250-Hp Coal-Burning Locomotive-Type Gas Turbine*

By JOHN I. YELLOTT and PETER R. BROADLEY

Locomotive Development Committee, Bituminous Coal Research, Inc., Dunkirk, N. Y.

INSTALLATION and coal-fired operation of the Houdry process turbine at Dunkirk, N. Y., were described in 1951. Last year a successful 250-hour test was run in which blade erosion was reduced to acceptable proportions. The installation of the Allis-Chalmers locomotive-type turbine was then completed and oil-fired operation was begun to "shake down" the machine and to determine its operating characteristics.

After the initial operating difficulties were overcome and the acceptance test run, the unit was subjected to a series of coal-fired tests which totaled 178 hours. The turbine was then dismantled to make a careful inspection and to carry out necessary alterations. The turbine was found to be in excellent condition, with no sign of deposits on the blading and only one very minor evidence of erósion.

Power Plant Installation and Details

The objective of the Locomotive Development Committee is to develop a coal-burning gas turbine for railroad service and the Dunkirk installation was therefore designed to conform to locomotive clearance requirements. The power plant and the coal preparation equipment are mounted on separate steel underframes, 10 ft wide and 50 ft long, simulating locomotive construction. Aside from the ducts which lead outside air to the compressor intake and return the exhaust to the atmosphere, all of the equipment can fit within the cabs of a two-unit locomotive.

The six-stage reaction turbine is designed to operate at 5700 rpm, with a maximum inlet temperature of 1300 F. The 21-stage axial compressor is coupled at its intake end to the turbine shaft; the discharge end of the rotor drives the four main generators through a reduction gear. The auxiliary generators (two 175-kw alternators, a 35-kw d-c generator and an exciter) are mounted above the main generators and driven by secondary gears.

Three sleeve bearings support the turbine and compressor shaft. The main lubricating oil pump is driven through the reduction gear, with a small d-c motor-driven auxiliary pump for use during starting and stopping periods. A pressure switch in the oil line starts the auxiliary pump whenever the pressure from the main pump falls below 4 psig. The heat picked up by the oil is dissipated by an air-swept oil cooler.

The regenerator is installed immediately above the turbine exhaust, the weight and end-thrust being taken by the steel framework. A bellows-type expansion joint provides the necessary flexibility between the turbine and the regenerator. The air from the compressor discharge enters the regenerator inlet header through a flexible elbow. A large blow-off valve, actuated by the overspeed protective devices, is mounted on this header.

Arrangement of Combustion and Ash Separation Equipment

Preheated air flows from the regenerator outlet header through expansion joints to the twin film-cooled combustors. Concentric dual-fuel burners are used in which the main coal burner surrounds the auxiliary oil burner. Ignition is accomplished by oil ignitors mounted on the head of the combustors.

Ash separation takes place in a large vessel, the internals of which consist of 26 ten-in. dia Dunlab tubes, mounted in parallel. These tubes discharge the ash continuously through a tangential blowdown line at the base of the tube. Continuous ash discharge is essential to prevent the incandescent particles from sintering and plugging the separation equipment. The individual blowdown lines are connected to manifolds which discharge the ash through concentrators to the collection system, and the cleaned air to the atmosphere. About 1.4 per cent of the heated air is blown down but part of the heat is recovered in the coal drying system.

The detailed designing of the combustion and ash separation equipment was carried out at Schenectady by the engineering staff of the American Locomotive Company, working closely with Locomotive Development Committee engineers. The design was complicated by the combination of high loads, caused by relatively high pressures and large diameters, and large thermal expansions, caused by the high temperatures and high coefficients of expansion. From a mechanical point of view, the separator is anchored at the pedestal adjacent to the turbine. The weight of the combustors is supported by the separator shell. When the unit becomes hot, the shell expands away from the turbine, thus pulling the combustors away from the regenerator. The combustor casings, cooler than the separator shell and made of different material, are free to expand axially back toward the turbine. The vertical expansions of the combustion and ash separation equipment are different from the expansion of the turbine and regenerator. All of these relative movements are accommodated by using toroidal expansion joints.

Coal Preparation System

The coal preparation system is designed to take regular locomotive run-of-mine coal, dry and pulverize it, and deliver it to the combustors at the rate required by the turbine. In the test installation, a track hopper conveyor delivers coal to the locomotive-type bunker, below which is a stoker-dryer which was designed and built by the Standard Stoker Company (now the Read-Standard Co.).

The stoker is powered by a 15-hp a-c motor, driving through a reversible hydraulic transmission. The coal first moves toward the rear of the stoker where it is crushed against breaker plates and divided into two streams which are brought forward by ribbon-type drying screws. The hot air, which flows countercurrent to the advancing coal, is obtained from the ash blowdown system. Two elevator screws lift the coal from the drying sections to a crushed-coal storage tank. A rotary level controller on this tank regulates the stoker operation.

Pulverization is accomplished by a B. & W. mill which is driven by a 50-hp a-c motor. The mill air is furnished by a blower which transports the coal from the mill, through two Dunlab separator tubes, to the pulverized-coal storage tank. The return air is collected into a manifold and returned to the blower inlet. Provision is made for introducing hot air at the blower inlet and for venting some of the return air to keep the system balanced. Crushed coal is delivered from its storage tank to the mill by a two-speed screw which is actuated by the level regulator in the pulverized-coal tank.

The original objective of the Locomotive Development Committee was to produce a self-contained locomotive which could take run-of-mine coal and do all of the processing on the locomotive. A re-evaluation of this aim is under way to determine if it will be more economical to use way-side preparation facilities and carry pulverized coal on the locomotive. This arrangement will greatly simplify locomotive operation and maintenance and reduce its cost to a figure which will be comparable with that of a 4500-hp diesel-electric locomotive.

The pulverized coal is fed from its storage tank into a pressurized conveying air line by means of a rotary coal feed-pump driven by a d-c motor through a variable speed transmission. The coal feed rate is remotely controlled from the operating panel by a Hagan pneumatic system which adjusts the transmission to give the desired feed-pump speed. A stream of compressed air carries the pulverized coal from the coal feed pump through a flow-splitter to the twin combustors.

Since the plant can burn either coal or oil, provision is made in the control system to transfer the fuel feed control air signal from the coal feed regulator to a valve in the fuel oil line. It is necessary to start the plant and bring it up to self-sustaining speed by burning diesel fuel, after which

* Excerpts from paper presented at American Power Conference, Chicago, March 26–28, 1952.

the fuel control system is transferred from oil to coal and load is applied.

Instrumentation

The entire plant is instrumented so that the performance of each component can be determined. Compressor discharge pressure is measured both by manometer and by a calibrated pressure gage on the control panel.

The four traction generators are loaded by G-E air-blown grid resistors, and the electrical output is measured by calibrated instruments. Turbine shaft power is determined by adding generator losses, gear losses, and auxiliary loads to the measured electrical output. At full load, these losses amount to about ten per cent of the turbine shaft power.

When the machine is being run under manual control, the operator adjusts the load by means of a rheostat which is connected in the field circuit of the exciter. The unit responds almost instantly to load changes, but its response to changes in fuel rate is considerably slower.

Overspeed protection of the turbine is provided by two separate safety devices. The first operates in conjunction with the governor to open the blowoff valve and reduce the fuel supply when the turbine reaches 3 per cent overspeed. Final protection relies upon a centrifugal trip on the end of the turbine shaft which goes into action when the turbine reaches 5 per cent overspeed.

Test Results

After the initial operating difficulties were overcome, a series of tests was run using diesel fuel. These covered the entire load range during a period when weather conditions caused compressor inlet temperature to vary from 60 F to 100 F.

The official acceptance test was run on September 28, 1951, between 11:30 a.m. and 1:00 p.m. During this period conditions remained substantially constant at 5710 rpm, 1285 F turbine-inlet temperature, and 59 F inlet-air temperature. Actual generator output was 3973 hp, giving a turbine shaft output of 4404 hp. Combustion efficiency by heat balance determination was 95.1 per cent. The cycle efficiency was 20.17 per cent. Correcting for heat loss from the fly-ash separator which was not insulated during the test, the cycle efficiency would be 21.2 per cent.

When the test results were corrected to the contract conditions (5700 rpm, 1300 F turbine inlet, 80 F compressor inlet) the unit was found capable of producing 4250 hp, or 13.5 per cent above the warranted output of 3750 hp. During the full load test, the turbine produced about 16,000 hp, of which the compressor took 11,600 hp. Turbine efficiency was 87.5 per cent; compressor efficiency was 84.0 per cent; regenerator effectiveness was 55 per cent, with pressure drops of 3.06 per cent on the air side and 6.5 per cent on the gas side.

Using the data from the variable load tests, Allis-Chalmers engineers calculated the performance of the plant over the entire load range for fixed inlet air conditions of 14.7 psia, and 80 F. The results of their calculations are shown in Table 1.

TABLE 1—ESTIMATED PERFORMANCE OF GAS-TURBINE POWER PLANT WITH 14.7 PSIA, 80 F INLET AIR

Turbine shaft, hp	21	2,130	3,830
Speed, rpm	4,500	4,500	5,100
Air flow to compressor, lb per hr	213,200	205,300	251,700
Air flow to compressor, cfm	48,400	46,600	57,100
Turbine inlet, F	700	1,100	1,300
Turbine exhaust, F	413	705	800
Regenerator exhaust F	386	541	622
Compressor discharge pressure, psia	52.9	58.3	75.1
Heat input to air, million btu per hr	16.43	28.85	43.66
Cycle eff, per cent	0.02	8.8	22.3

Maximum cycle efficiency is reached at 75 per cent of full power. Beyond that point, the compression ratio rises beyond the optimum value and the regenerator makes a smaller contribution to the cyle. The idling fuel consumption is more than had been anticipated because of the high idling speed necessary to stay above the pumping range of the compressor.

Following a demonstration of the plant to the Locomotive Development Committee on November 20, 1951, it was decided to dismantle the machine for a careful internal inspection.

Coal-fired Operation

As soon as the acceptance test had been successfully completed, the fuel controls were turned from oil to coal and the plant was operated for a total of 178 hours on Pittsburgh-seam high-volatile bituminous coal. The machine operated as well with coal as with oil, and, in general, it was impossible for a casual observer to tell whether the plant was burning oil or coal. The stack was relatively clear and the ash disposal system worked satisfactorily. Combustion efficiency, as determined by ash analysis, was consistently above 95 per cent. Trouble was encountered with damp coal and a number of alterations had to be made in the coal system. The width of the coal feed-pump rotor had to be increased to 5.0 in., and the method of venting the pump was altered. The duration of the coal-fired tests ranged from a few hours to a maximum of 43 hr. Average temperature at the turbine inlet ranged between 1050 and 1100 F, with loads varying from 1500 to 2500 hp depending upon turbine speed and outside air temperature.

A number of mechanical difficulties were encountered, including troubles with auxiliary generator lubrication overspeed trips, hot air leakage at the turbine inlets, and rubs of increasing severity in both turbine and compressor. Experience with the Houdry Unit had led to the expectation that erosion might be encountered in the cylinder blading, but a careful examination of the entire turbine showed only one very small spot of erosion. There were no deposits of ash anywhere in the turbine and the labyrinth seals were all perfectly clean. The rubs in the turbine and compressor were quickly located, and clearances were increased where it was found necessary. The leakage of hot air at the turbine inlet was traced to a bolting condition which was corrected. The machine has been reassembled and is now undergoing a 750-hr high-temperature, high-load test.

Corrosion Testing at Harbor Island*

On April 23 and 24 a group of technical editors was afforded a firsthand opportunity to inspect the International Nickel Company's corrosion testing facilities at the marine testing station at Harbor Island, near Wrightsville Beach, N. C., and the facilities for studying the effects of sea spray and the atmosphere at nearby Kure Beach.

Among the new facilities at Harbor Island is a full-sized salt water evaporator and distillation unit to study the effects of water treatment and design on the scaling of such units. A two-story laboratory building has been erected to house the evaporator, which is served by a 4000-lb per hr boiler.

At Kure Beach, a new sea-spray test lot has been erected about 80 ft from the shore, providing a capacity of almost three times that of the former test lot. Inco engineers pointed out that comparative tests, first at Kure Beach and now at Harbor Island and in synthetic sea water in the laboratory, have shown definitely that laboratory conditions are quite inadequate for measuring the behavior of metals and alloys. In these sea water tests most specimens are exposed on racks which are continuously immersed at a depth of from two to seven feet, depending upon the tide level. Facilities have also been provided for hanging specimens from a large pontoon float, when it is desired to maintain a constant water line or a constant depth of immersion in spite of the rise and fall of the water with the tides.

Velocity Effects

The need for more precise information on the abilities of alloys to withstand the severe erosive effects associated with such uses as condenser tubes, piping systems, pump impellers, propellers and other underwater parts of fast moving ships has led to the design and operation of several types of erosion testing apparatus. There is the EES erosion testing apparatus, developed by the U.S. Naval Engineering Experiment Station at Annapolis, by means of which specimens in the form of bars or tubes are whirled through violently agitated sea water at velocities up to 30 ft per second.

Another type of apparatus is a battery of rotating spindles to which are attached test pieces in the form of disks which are rotated at high speed in sea water. This type of specimen and motion provide a velocity gradient from center to periphery and demonstrate clearly the critical velocities above which the protective films are unable to adhere.

The aspirator type of jet testing apparatus, developed at Kure Beach, subjects test specimens to the erosive effects of high velocity jets of sea water mixed with air bubbles. It has been particularly useful in developing and evaluating condenser tube alloys resistant to "impingement attack."

For studying the action of sea water flowing at moderate velocities, specimens are immersed in troughs, the total length of which amounts to about 600 ft and accommodates several hundred test pieces.

The use of full-size units in this way has the advantages over ordinary shipboard trials that operation can be made continuous or to follow any desired cycle, and the conditions of use can be altered at will to suit the requirement of the test program without the restrictions imposed by the operating requirements of shipboard installations.

Effect of Marine Fouling

The study of the antifouling characteristics of metals, alloys, plastics and protective coatings has been an important phase of Inco's research program. Specimens are fastened to the rack by Monel screws. Galvanic effects are prevented by the use of bakelite insulating tubes over the bolt shanks and insulating washers between the specimens and the racks and the washers under the bolt heads. The adequacy of this method and a modification of it has been demonstrated by the absence of such effects on specimens of such materials as magnesium, aluminum, and zinc-coated steel. Exposure period may vary from six months to several years.

Atmospheric Racks

Since corrosion by marine atmospheres is equal in importance to corrosion by salt water, facilities have been provided for extensive atmospheric corrosion tests. Up to the present time, over 25,000 specimens have been exposed by Inco and cooperating companies. Located 250 yd from the ocean shore, the test racks face south and the specimen frames are set at a slope of 30 deg from the horizontal. New specimens of certain key materials are put on the racks each time a large group is removed, or a new group is installed. These key specimens provide information on changes in the corrosivity of the atmosphere itself from year to year which assists in the interpretation of the results of tests made over different time periods.

In order to provide for more drastic conditions of exposure to salt air and sea spray, another group of test racks has been located about 80 ft from the shore line. Their close proximity to the surf breaking on the adjacent beach makes the corrosive conditions very severe, some steels being corroded ten times faster here than in the main test lot further from the ocean.

* Reported by J. J. Jaklitsch, Jr., technical editor, *Mechanical Engineering*.

ASME Semi-Annual Meeting Program

CINCINNATI, Ohio, will play host to the 1952 ASME Semi-Annual Meeting, which is to be held at the Hotel Sheraton-Gibson on June 15–19. Among the featured speakers will be William C. Foster, Deputy Secretary of Defense, who will have as his topic, for the Roy V. Wright Lecture, "Technology in a Troubled World"; Piero Ferrerio, president of the Italian Edison Company in Milan, whose Rice Lecture subject will be "Past, Present and Future of the Italian Power Industry"; Julian E. Tobey of Appalachian Coals, who will address the banquet on "Romance of Power and Fuels"; and R. J. S. Pigott, whose topic at the ASME President's Luncheon will be "The Position of the Engineer in These Times."

Portions of the program which are of general and specific interest to engineers in the steam power field include the following:

Monday, June 16, 9:30 a.m.

"Design, Installation and Application of Fuel Burning Equipment for 25-hp Range to Prevent Air Pollution" by Charles W. Gruber, Cincinnati.

"Proper Design, Installation and Application of Coal Burning Equipment for Boilers (25–500 hp) to Prevent Smoke and Air Pollution" by H. C. Ballman, Columbus, Ohio.

"The Problem and Solution for Plants with Capacity of 100 to 1200 lb per hr" by E. C. Webb, Iron Fireman Corp.

"Analyzing Fuel-Burning Equipment to Prevent Air Pollution" by C. E. Miller, Combustion Engineering-Superheater, Inc.

Monday, June 16, 2:30 p.m.

"Properties of Coal—Their Influence on Performance of Coal Burning Apparatus" by B. E. Tate, Jr., National Cash Register.

Monday, June 16, 8:00 p.m.

"What Does Industry Have to Offer the Young Engineer?" by Ralph Scorah, University of Missouri; J. L. Knight, General Electric Co.; and C. T. Wasmer, Rex Engineering Corp.

"Operating Experiences on the Mechanical Joint Connecting Austenitic-Ferritic Materials in the Main Steam Line at Ridgeland Station" by E. C. Bailey, Commonwealth Edison Co.; H. C. Schroeder, Sargent & Lundy; and I. Carlson, Crane Co.

Tuesday, June 17, 9:30 a.m.

"Material Handling Facilities at Walter C. Beckjord Station" by R. F. Schierland, Cincinnati Gas & Electric Co.

"Features of New Steam Plants" by G. V. Williamson, Union Electric Co.

"Design for Extreme Flood Conditions at Paddy's Run Station" by D. C. Hormell, Pioneer Service & Engineering Co.

"Special Features of Milesburg Power Station" by R. A. Mycoff and W. F. Drake, West Penn Power Co.

Wednesday, June 18, 9:30 a.m.

Symposium on selection and training of operating personnel for central stations presented by engineers from Public Service Co. of Indiana, Dayton Power & Light Co., American Gas & Electric Service Co., Dow Chemical Co., and Commonwealth Edison Co.

(Continued from page 64)

unnecessary build-up of pressure in the system.

Power Characteristics with Variable Speed. Fig. 11 shows typical power characteristics based on the performance of the first-stage variable-speed feed pump multiple-unit and single-unit operation. The top group of curves is for the multiple system and curve *A* is the electrical horse-power input to the motor at constant speed. Curves *B* and B_1 are the ideal curves for maximum and minimum steam-drum pressure conditions respectively, assuming the developed pressure closely follows the system characteristics. Curve *C* shows the electrical horse-power input when speed control is by means of rotor resistance and includes the additional losses in the motor which are approximately proportional to the speed reduction. Curve *D* is for hydraulic coupling control, and in addition to the power loss proportional to speed reduction (as for rotor resistance) there is a loss due to the initial slip of 2–3 per cent, plus coupling windage, so that the power absorbed at maximum output is actually increased. The two lower groups of curves are for the unit system, showing the comparative performances for both methods of speed control, and they indicate the increased economy that is possible with the unit system of operation. The power at constant speed is approximately equally divided between the first- and second-stage units, so that the overall saving in power is only about half the amount shown. Under blow-off conditions curves *C* and *D* apply throughout.

Relative Merits of High-Temperature Feed Pumps and High-Pressure Heaters

There are two alternative systems in general use. One is to place the heaters after the feed pumps, so that the heaters are subject to the full discharge pressure while the feed pumps deal with water at medium temperature. The other is to place the pumps after the heaters so that the pumps deal with high-temperature water while the heaters are subject to only moderate pressure.

For the feed pumps there need be no problem, as for many years past they have been in regular service on temperatures around 400 F and they have been equally satisfactory as pumps working on lower temperatures. If, therefore, there is reluctance to install high-pressure heaters, then high-temperature feed pumps provide the solution. However, with this arrangement it is necessary to divide the feed-pumping into two stages, the first stage providing sufficient pressure to obviate flashing on leaving the heaters and to avoid cavitation at inlet to the second-stage pump. Two-stage pumping therefore requires more floor space, more valves and piping, and control and operation are more complicated. On the other hand, pumps designed for medium temperature are of simpler construction, but the lower cost must be weighed against the higher cost of high-pressure heaters.

Another important consideration to be taken into account in assessing the relative merits of the two arrangements is that high-temperature pumping in conjunction with medium-pressure heaters is less economical in fuel consumption than is the alternative scheme, independently of any difference in pump efficiency.

When water is fed into a boiler at a given weight rate and against a given pressure, the energy to be imparted to the water is inversely proportional to the specific gravity. So the higher the temperature of the feed-water the greater the power required for boiler feeding and, therefore, the more important is the need for the most economical arrangement.

The energy is provided partly by the feed pumps and partly by the heaters. If the overall efficiencies (fuel/water) for pumps and heaters be taken approximately as 20 and 80 per cent respectively, it is apparent that greater economy is secured by making the heaters do as much of the work as possible. This can be achieved by arranging the pumps at the inlet, rather than the outlet, side of the heaters.

In scheme *a* the feed pump raises the pressure to 2020 psig before the water passes through the heaters, and it will be noted that in addition to raising the temperature, the heaters supply the energy equivalent to lifting the water from 4780 to 5380 ft (4780 ft = 4830 ft minus 50 ft loss in heater). In scheme *b* two-stage pumping is required, the first stage supplying a pressure of 320 psig to prevent vaporization of the water entering the second stage. The heaters supply only a small proportion of the energy to the water on account of the low pressure.

The following figures show the comparative performances of the two schemes:

Work to water per lb of feedwater, in ft-lb

At 200 F, 1 psig = 2.39 ft of water
At 400 F, 1 psig = 2.69 ft of water
Increase per 1 psig = 0.3 ft of water

Pump(s)	Heaters	Total
Scheme *a*		
(2000×2.39) $= 4780$ (89 per cent)	(2000×0.3) $= 600$ (11 per cent)	5380 ft-lb (100 per cent)
Scheme *b*		
$[(300 \times 2.39) + (1700 \times 2.69)]$ $= 715 + 4575$ $= 5290$ (98.5 per cent)	(300×0.3) $= 90$ (1.5 per cent)	5380 ft-lb (100 per cent)

Equivalent B.t.u.'s required from fuel per lb of feed water

Pump(s)	Heaters	Total
Scheme *a*		
$\frac{4780}{0.20 \times 778} = 30.70$	$\frac{600}{0.80 \times 778} = 0.97$	31.67 Btu
Scheme *b*		
$\left(\frac{715}{0.20 \times 778} + \frac{4575}{0.20 \times 778}\right) = (4.60 + 29.40) = 34.0$	$\frac{90}{0.80 \times 778} = 0.15$	34.15 Btu

Thus boiler feeding scheme *b* requires $7^1/_2$ per cent more fuel than does scheme *a*.

Annual Smoke Prevention Meeting

The Hotel Statler, Cleveland, will be the scene of the Forty-Fifth Annual Meeting of the Air Pollution and Smoke Prevention Association of America on June 9–12. Walter O. Everling, director of research of the American Steel and Wire Company, will serve as chairman of the Convention, and H. G. Dyktor, Cleveland's Commissioner of Air Pollution Control, is heading the committee of local arrangements. The following program has been scheduled:

Monday, June 9

Committee meetings and round-table discussion by smoke inspectors.

Tuesday, June 10

"Pilot Plant Studies of Dust Collection for Open-Hearth Stacks" by **G. M. Dreher** of Jones & Laughlin Steel Corp.

"Some Aspects of Air Pollution in the Steel Industry" by **Dr. C. A. Bishop** of U. S. Steel Corp.

"An Industrial Stack Sampling Program" by **J. C. Radcliffe** of Ford Motor Co.

"The Foundry Equipment Manufacturers' View of Air Pollution Advances" by **J. M. Kane** of American Air Filter Co.

"Application of Scrubbing Devices for Odor and Fume Control" by **E. P. Krop** of Standard Oil Co.

"Combustion of Oil in Small Commercial Heating Units" by **Jack Gordon** of North American Mfg. Co.

"Eye Irritants Formed by Interaction of Styrene and Halogen in the Atmosphere" by **E. M. Adams** of Dow Chemical Co.

"Chemical Plant Air Pollution Control" by **H. C. Hosford** of E. I. du Pont de Nemours & Co.

"HF Tail Gas Absorption" by **R. W. Tomlinson** of the Pennsylvania Salt Mfg. Co.

Wednesday, June 11
Morning Session

"The Combustion of Solid Fuels—Effect of Coal Quality on Boiler Performance and Air Pollution' by **Otto de Lorenzi** of Combustion Engineering-Superheater, Inc.

"Water-Tube Boilers and Their Design When Fired by Spreader Stokers and Their Relation to Air Pollution" by **E. C. Miller** of Riley Stoker Corp.

"Spreader Stokers and Their Relation to Air Pollution" by **Max Funk** of Combustion Engineering-Superheater, Inc.

"What the Mechanical Type Dust Collector Industry Is Doing to Meet the Problems Presented by Spreader-Stoker-Fired Water-Tube Boilers" by **P. F. Best** of The Thermix Corp.

Afternoon Session

"Problems Encountered in the Conversion of Existing Large Coal-Fired Boilers to Conform with Present-Day Air Pollution Codes" by **R. W. Van Duzer** of The Detroit Edison Co.

"Application and Performance of Modern Dust Recovery Equipment on Large

Coal-Fired Boilers" by **L. W. Cadwallader** of Potomac Electric Power Co.

"Economic Aspects of Air Pollution Control" by **C. L. Smith,** Cleveland Chamber of Commerce.

Thursday, June 12

Morning

Business Session.

Afternoon

"Health Aspects of Air Pollution" by **Dr. R. A. Kehoe** of College of Medicine, University of Cincinnati.

"A Rational Approach to Air Pollution Legislation" by **George E. Best.**

"The Legal Aspect of Air Pollution Ordinances" by **J. A. Crowley,** director of law, City of Cleveland.

The annual banquet will be held Wednesday evening and will be addressed by **Mayor Thomas A. Burke** of Cleveland.

Wisconsin Power Conference

The annual Wisconsin Power Conference and Exposition will be held at the Schroeder Hotel, Milwaukee, on June 11–13. The tentative program calls for sessions the first day on plant safety and codes; fuels, combustion and industrial wastes the second day; and power plant records, operation and refrigeration insulation the third day.

R. C. Johnson, president of Siesel Construction Co., is scheduled to talk on the general scope of codes and on the state law requiring registration of architects and engineers. Building codes will be discussed by G. M. Kuetemeyer of Milwaukee's Building Inspector's Office and the Electrical Code by George Andrae.

Ray Jolley, of Consolidated Water Power & Paper Co., has agreed to talk on burning calcium base and ammonium base sulfite waste liquor under a boiler; and disposal of wastes other than those from paper mills will be discussed by Mr. Hieseck of the Milwaukee County Sewage Commission.

Obituaries

Edward Tait, manager of the Fabricated Products Department of Combustion Engineering-Superheater, Inc., died on April 12, at the age of 65. A native of Scotland, Mr. Tait received his engineering education at the Glasgow and West of Scotland Technical College. During his engineering career he was employed by the Newport News Shipbuilding & Drydock Co., the Chester Shipyard, and Federal Shipbuilding & Drydock Corp. before joining Combustion Engineering in 1927.

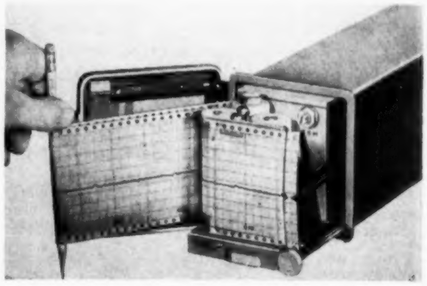
Forrest Nagler, who retired March 1 as manager and chief engineer of Allis-Chalmers atomic power section, died April 1. He was 66 years of age.

A graduate mechanical engineer from the University of Michigan, he specialized in hydraulic and marine engineering and entered the company's hydraulic department in 1908. He was made chief mechanical engineer of the engineering development division in 1942 and was named to the atomic power section post in June 1949.

New Equipment

Strip-Chart Recorder

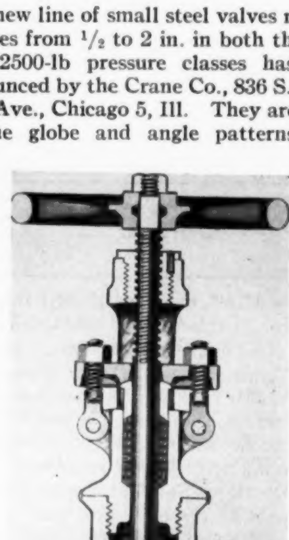
An independently powered strip-chart recorder with an electronically actuated pen is announce by the Swartwout Company, 18511 Euclid Ave., Cleveland 12, Ohio. Known as the Autronic recorder, it is an electronic servo-powered null-balance device. Unbalance between the output of the primary element transmitter



and the balancing transformer is amplified to drive the rotary-solenoid motor for positioning the pen, which is actuated independent of the chart drive. The recorder is extremely compact, measuring $4\,^5/_8 \times 5$ in. on the control board. It may be used interchangeably without recalibration for circuits controlling temperature, pressure, level or flow.

Lip-Seal Valves

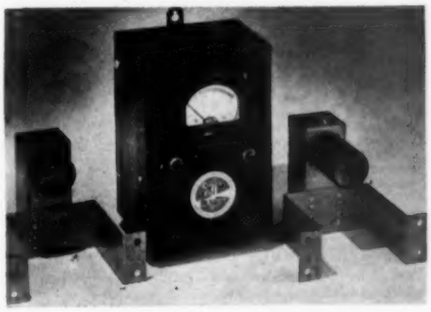
A new line of small steel valves ranging in sizes from $^1/_2$ to 2 in. in both the 1500 and 2500-lb pressure classes has been announced by the Crane Co., 836 S. Michigan Ave., Chicago 5, Ill. They are made in the globe and angle patterns with



either socket-welding or screwed ends. A distinguishing feature is the Lip-Seal bonnet joint consisting of long body-bonnet threads which are pulled up until contact is made between flat surfaces on the shoulder of the bonnet and the top of to body. The small lips around the edge are then seal welded.

Smoke Indicator

Cleveland Fuel Equipment Co., 7316 Associate Ave., Cleveland 9, Ohio, has added a smoke indicator and control to its line of products. The equipment consists of a light source, a photoelectric cell whose output is proportional to the density of the smoke, and a master control in which is incorporated an amplifier, relay,



smoke density meter calibrated in Ringelmann units, and signal lights. The master control may be located remotely and can be set for a predetermined smoke density. A non-adjustable time delaying circuit permits a small amount of smoke to pass before starting the control, thereby eliminating cycling of equipment.

Business Notes

The Power Chemicals Div. of **E. F. Drew & Co.** announces that J. S. Beecher has been placed in charge of proposals and general technical work, and that Charles Clodi will have charge of the Water Laboratory in addition to assisting Mr. Beecher.

The Dampney Co. has appointed M. H. Hilt of Fort Wayne, Ind., as sales and service representative in that area.

Combustion Engineering-Superheater, Inc., has appointed Francis J. Dolan general manager of its Superheater Company Div. (railway) succeeding Bard Browne who retired on March first. Mr. Dolan joined the predecessor company (Locomotive Superheater Co.) in 1920.

General Electric Co. has named Alan Howard manager of the Electric Turbine Division's engineering department and J. P. Keller manager of the gas turbine department.

Hall Laboratories, Inc., Pittsburgh, has made H. M. Rivers assistant director of engineering service, succeeding J. N. Welsh who recently assumed new business administrative duties.

Manning, Maxwell & Moore, Inc., has appointed Morris S. Palmer manager of field sales and Raymond F. Attner product manager of Hancock valves.

Hagan Corp., Pittsburgh, has a new research and development laboratory nearing completion at Orrville, Ohio, which will be known as the "J. M. Hopwood Research Building" in memory of the founder of the corporation. Apparatus for frequence-response testing of all kinds of components of control systems and instruments will be developed and tested here.

NEW CATALOGS AND BULLETINS

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 18, N.Y.

Combustion Control

A detailed account of tried-and-proved automatic combustion control techniques for oil and gas-fired boilers is now available from Bailey Meter Co. in a 24-page three-colored bulletin (No. 1023). Comprehensive illustrations and descriptions include diagrammatic sketeches showing nine typical firing methods and 16 major control equipment components. There are also individual facts and figures on 300 installations throughout the United States, ranging from 6000 to 1,000,000 lb of steam per hour capacity.

Deaerating Heaters

A 12-page bulletin, WC-106, on tray-type deaerating heaters has been made available by Graver Water Conditioning Co. In an introductory section the principles of successful deaeration and essential elements of a deaerating heater are explained. Special features are described in tabular form and are illustrated by detailed drawings in which principal parts are identified.

Flow Meter Handbook

A 40-page handbook has just been published by Fischer & Porter Co. to aid in the selection and sizing of variable-area meters. It contains, in condensed form, the results of a fifteen-year period of research on the part of the Company. A description of variable-area meters, tubes and flats and their comparison with variable-head meters, as well as calibration prediction data, has been included.

Water Treatment Unit

Infilco Incorporated has released a bulletin describing a complete-package water treatment unit to handle from 5 to 100 gpm. It provides a water equal or superior to large municipal supplies for field crews or small domestic supplies, boiler feed, engine cooling or chemical and manufacturing process. The unit softens, clarifies, sterilizes or removes organic matter, tastes or odors.

Refractories

In a 12-page illustrated brochure just published by Johns-Manville five different J-M Firecrete products for casting special refractory shapes and three J-M Blazecrete products for gunning and slap-troweling applications are presented. It also contains suggestions for solving maintenance problems as well as recommendations for casting shapes and linings. Photographs show typical uses and illustrate handling methods.

Speed Reducers

A 48-page bulletin describes the complete line of double-worm and helical-worm gear speed reducers manufactured by the De Laval Steam Turbine Co. Extensive data are included on horsepower, output torque and center distances for reductions up to 6400:1 Detailed information on how to select this type of gearing, horsepower rating tables, dimension sheets and complete physical data add to the usefulness of the bulletin.

Ratio Totalizer

The Ratio Totalizer, a pneumatically operated control mechanism which is widely applicable for accurately combining input control pressures and spring forces; and producing an output control pressure based on addition, subtraction, multiplication, division or more complicated functions of input control signals, is described in Bulletin 5452 issued by the Hagan Corporation. It is said that the accuracy of the output signal is within one per cent of full scale reading.

Hot-Process Water Softeners

A 32-page booklet, No. 2341, containing interesting data on the hot-process treatment of boiler feedwater has been prepared by The Permutit Company. Several types of designs are illustrated and described, including the conventional and sludge-blanket types, with and without built-in deaerating equipment. Also described is the two-stage hot-process lime and zeolite softener, with which it is possible to secure feedwater low in alkalinity, silica content and hardness.

Sump Pumps

Warren Steam Pump Co., Inc., announce improved models of Types VS and VN sump pumps which are illustrated and described in an eight-page two-color bulletin WQ-220. These pumps are available in wet and dry pit types and are adapted to handling clear liquids, sewage and other liquids containing solids in sizes $1^1/_2$ in. to 8 in., capacities to 1000 gpm and pressures to 250 psig.

L&N Thermohms

The line of general-purpose and specialized "Thermohms" (resistance thermometers) that are being used in plant and laboratory applications to detect temperatures between —325 and +1000 F, with accuracies from $\pm$0.018 F to $\pm$3.0 F, are described and illustrated in a new, 36-page catalog and buyer's guide, "Thermohms, Assemblies, Parts and Accessories," just published by the Leeds & Northrup Company.

To aid in the choice of the correct Thermohm, this publication features a 5-page tabular guide which indicates the Thermohm to use for each of the numerous applications in the ceramics, chemical, food and drug, glass, iron and steel, nonferrous metals, petroleum, power, plastics, and textile industries. This guide also describes how the Thermohm is used and tells where it is usually installed. Many additional pages provide information about the temperature conditions, corrosive agents, pressures, gaseous or liquid flows, and other process conditions to which the elements can be exposed.